Moody Tower Measurements – Overview

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W. Luke, S. Brooks (NOAA-ARL)
J. Stutz (UCLA)
P. Chuang (UCSC)
D. Atkinson (Portland State U)
R. Griffin, J. Dibb (UNH)
R. Weber (GATECH)
M. Fraser (U Rice)
C.J. Flynn (PNNL)

Moody Tower Measurements – Overview

Rappenglueck (PI), Lefer (Co-PI) Main Funding: HARC

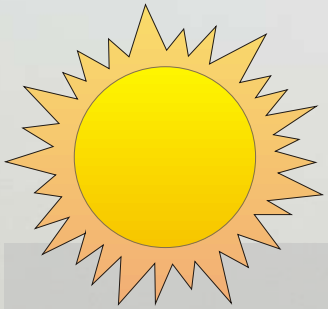
Measurement Site

- UH - Moody Tower

Research Issues

- What are the main sources and sinks for radicals in the urban air of Houston?
- What processes determine the radical budget in the urban air of Houston?
- What are the impacts with regard to the formation of secondary species?
- What are the anthropogenic vs biogenic contributions to photochemical processes in Houston?

Photochemical Processes



Termination by NO_x

Photolysis of O_3, RCHO, HONO

HNO_3

NO_2

$+ H_2O$

OH^*

O_3

O_2

$O(^1D)$

O

NO

RCH_3

CO

RCHO

H_2O

CO_2

H_2O

RCH*

$RC(O)O^*$

$+O_2$

RCH_2O^*

$+O_2$

RCO*

H*

$RC(O)O_2{}^*$

$+O_2$

$+O_2$

$+O_2$

$HO_2{}^*$

$RCH_2O_2{}^*$

PAN's

PAN
PPN (anthropogenic)
MPAN (biogenic)
....

Termination by $RO_x + RO_x$

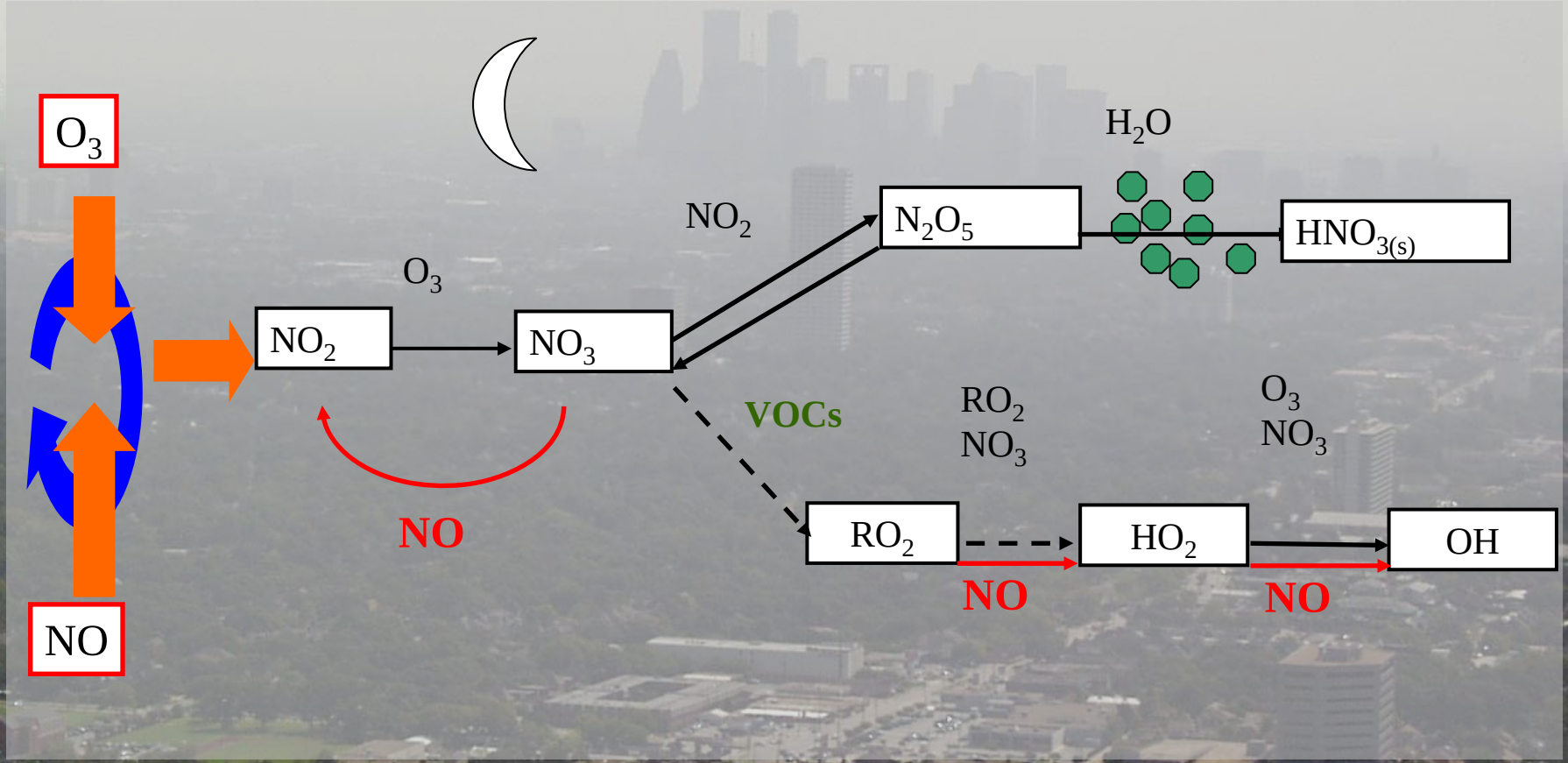
H_2O_2

$+HO_2{}^*$

RCH_2OOH

$+HO_2{}^*$

Nighttime Chemical Processes

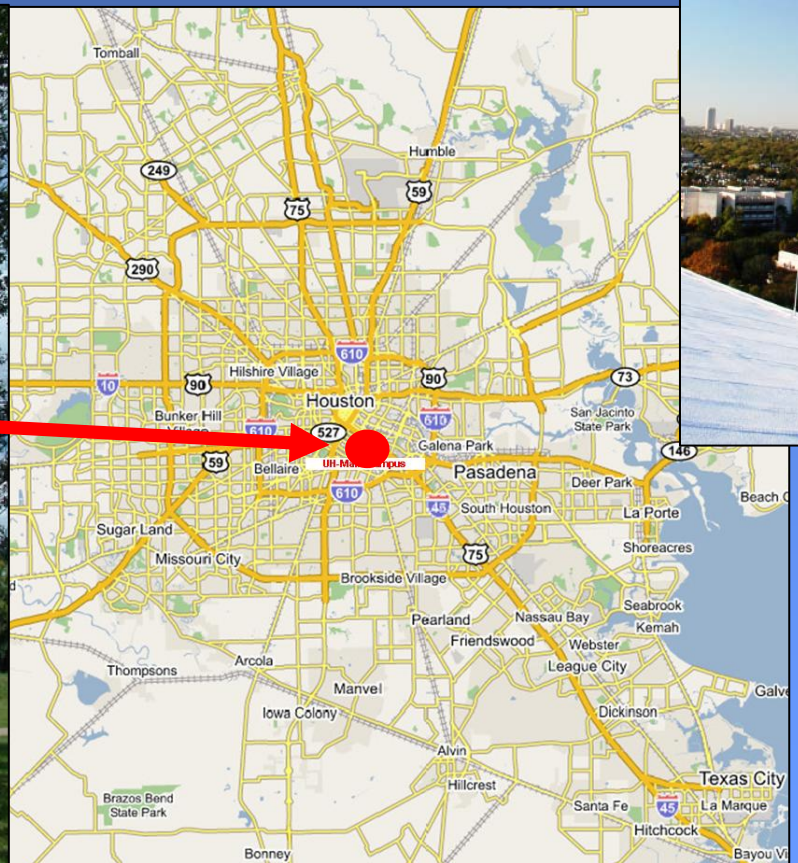


Moody Tower – Measurements: PIs - Organizations

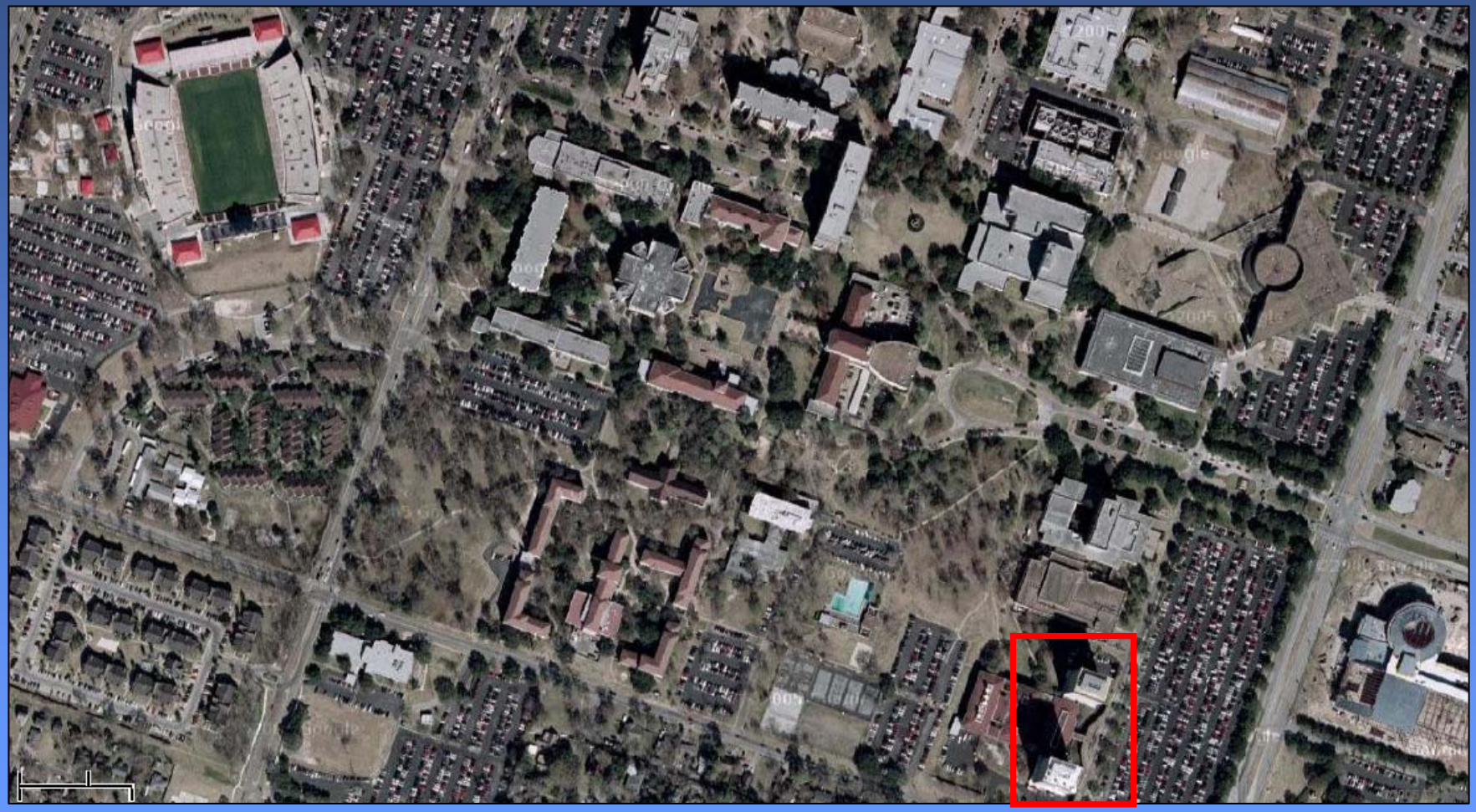
- Meteorological parameters (B. Lefer & B. Rappenglueck, UH)
- O_3, CO, NO, NO_2, NO_x (B. Lefer & B. Rappenglueck, UH)
- PAN, PPN, MPAN, online VOC, offline VOC, HCHO, H_2O_2 (B. Rappenglueck, UH)
- photolysis of O_3, NO_2, HONO, HCHO and 16 other important photolysis reactions, UV/VIS AODs, O_3 Column, Cloud Camera (B. Lefer, UH)
- CO, NO_Y, SO_2 (W. Luke, NOAA)
- DOAS: O_3, NO_2, NO_3, N_2O_5, HONO, HCHO; Maxdoas: NO_2, HCHO (J. Stutz, UCLA)
- OH, HO_2, RO_2, OH reactivity, O_3, NO, NO_x (W. Brune, PSU)
- Oxy-VOCs, HNO_3 (R. Zhang, TAMU)
- HCHO, C_2H_4 (M. Fraser, U Rice)
- Aerosol composition, EC/OC (R. Griffin, UNH)
- Water soluble organic carbon gases and aerosols , HNO_3, HONO (J. Dibb, UNH)
- PM2.5: Mass, EC/OC, Water soluble organic carbon (R. Weber, GATECH)
- elemental, particle bond and reactive gaseous Hg (S. Brooks, NOAA)
- Cloud Condensation Nuclei (P. Chuang, UC-Santa Cruz)
- Aerosol Scattering and Extinction (D. Atkinson, Portland State)
- Aerosol size distribution (D. Collins, S. Brooks, TAMU)
- Aerosol backscatter remote sensing (C. Flynn, PNNL)

Moody Tower: Site Properties

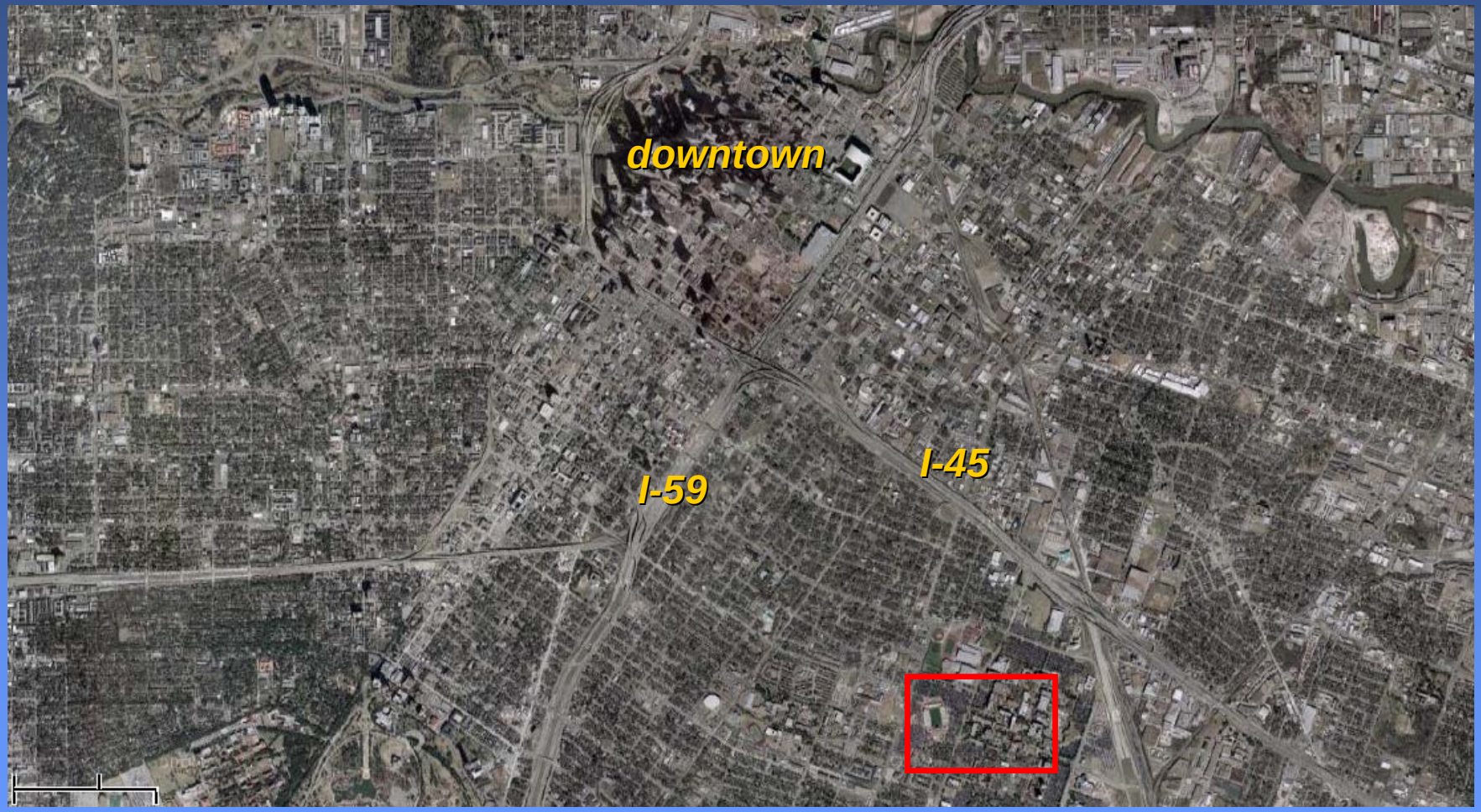
- 60 m a.g.l.
- south of downtown Houston



Moody Tower:
Overhead View UH Campus



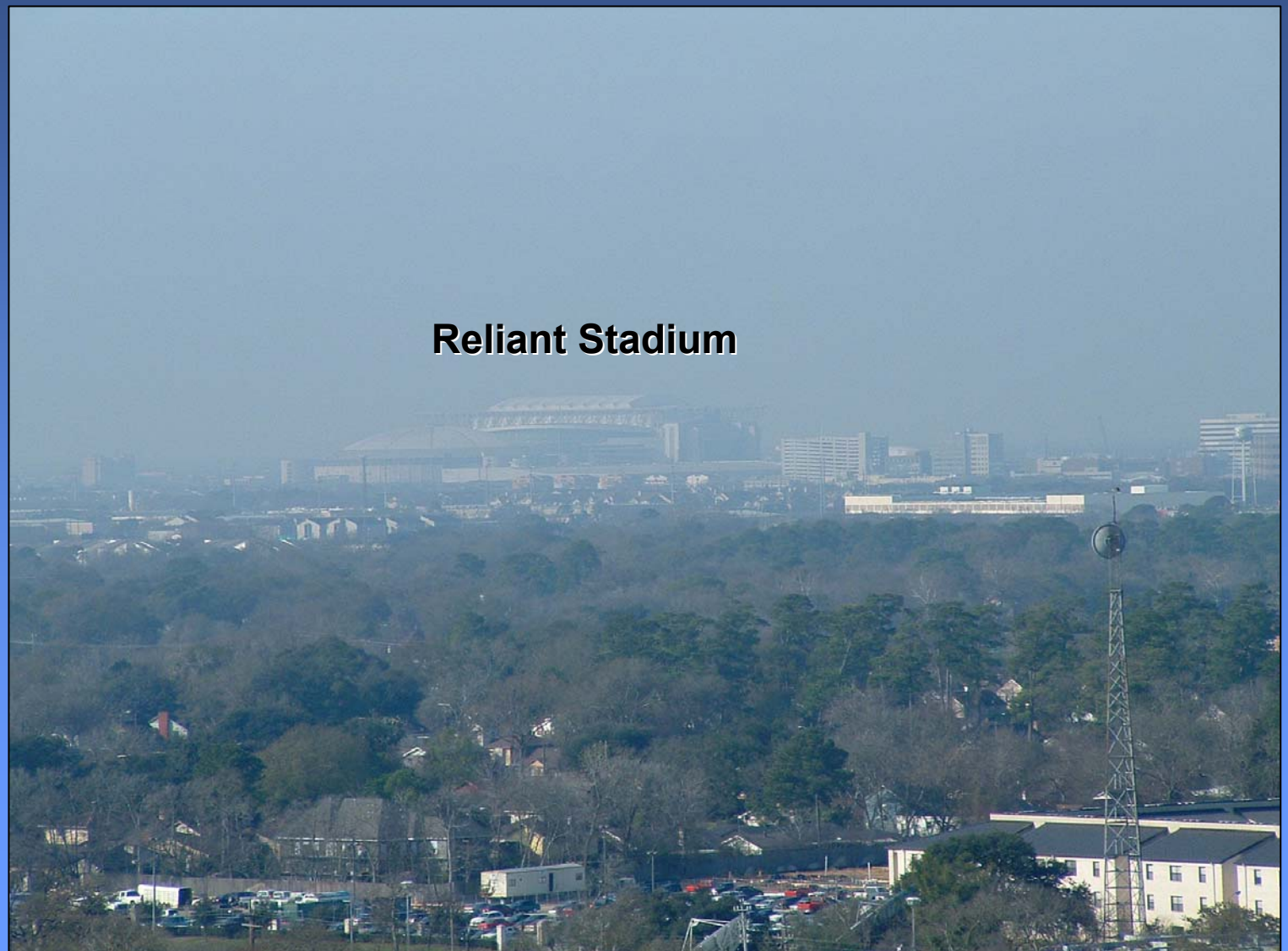
Moody Tower: Overhead View Downtown



Moody Tower:
View NNE

Moody Tower: View West

Moody Tower: View SW



Moody Tower: View S

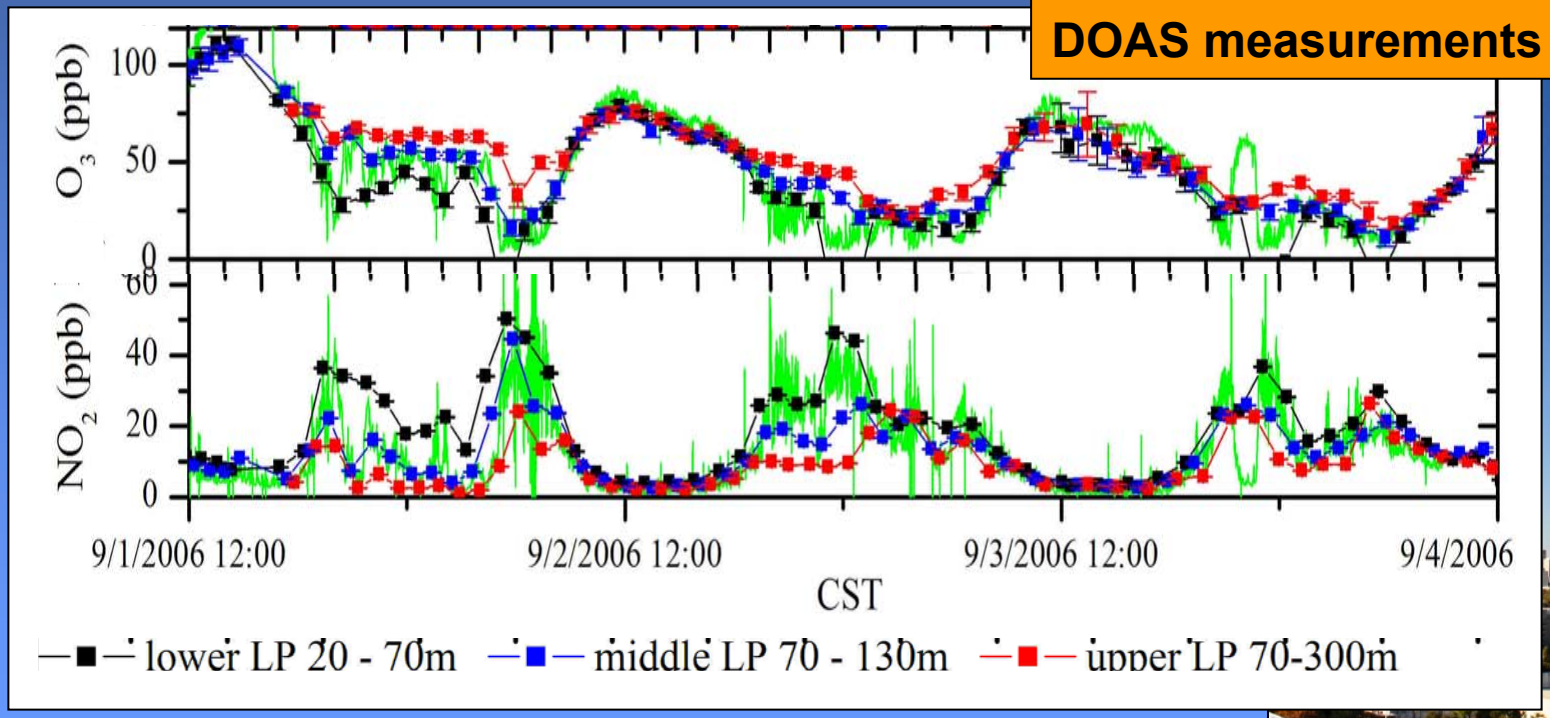
Moody Tower: View SE

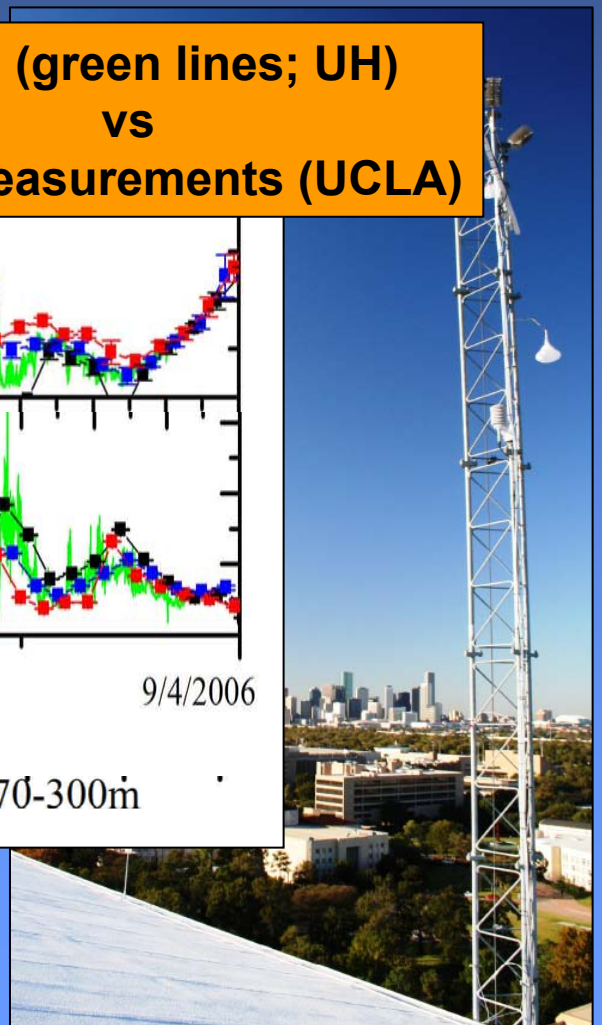
Moody Tower: View ENE

Moody Tower: Site Properties

- 60 m a.g.l.
- south of downtown Houston
- representative

in-situ (green lines; UH)
vs
DOAS measurements (UCLA)





Moody Tower: Site Properties

- 60 m a.g.l.
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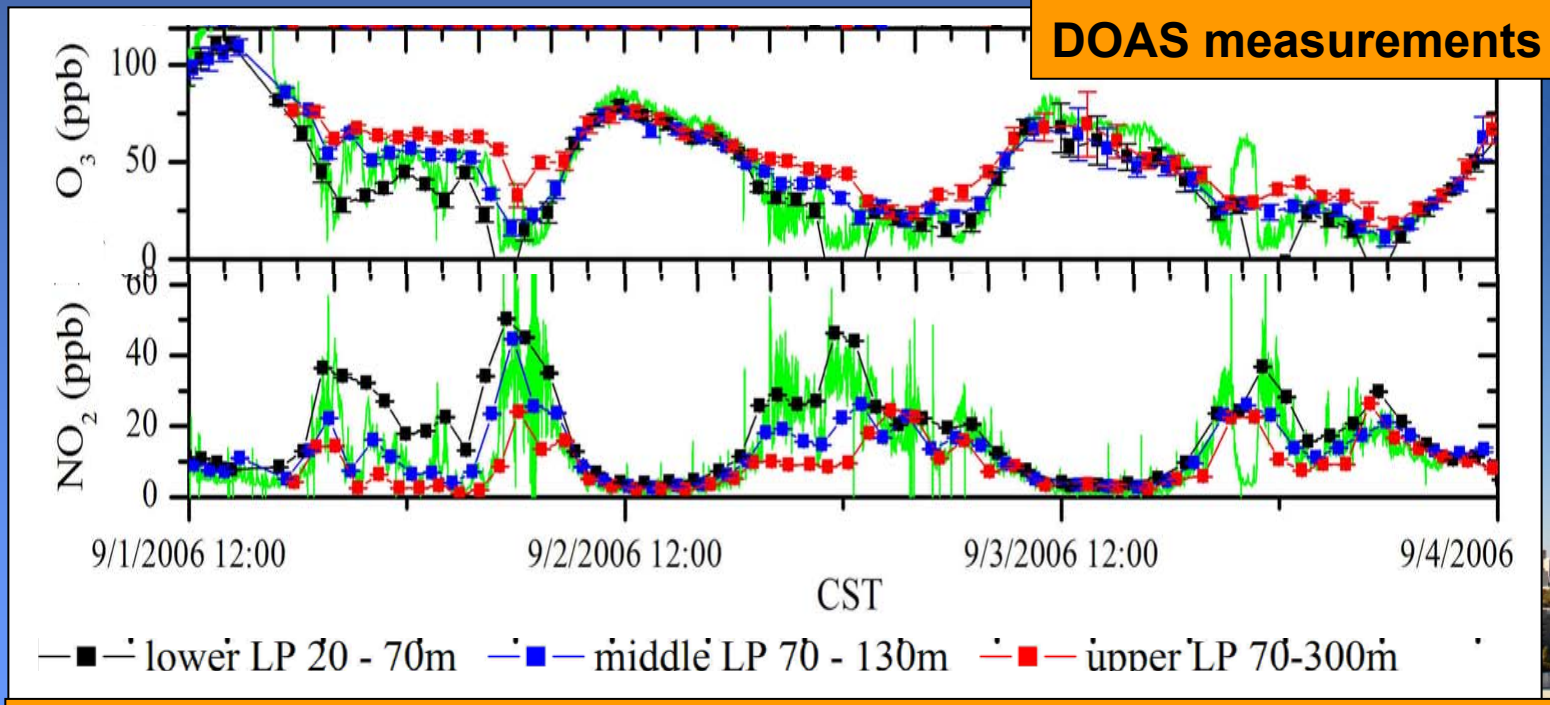
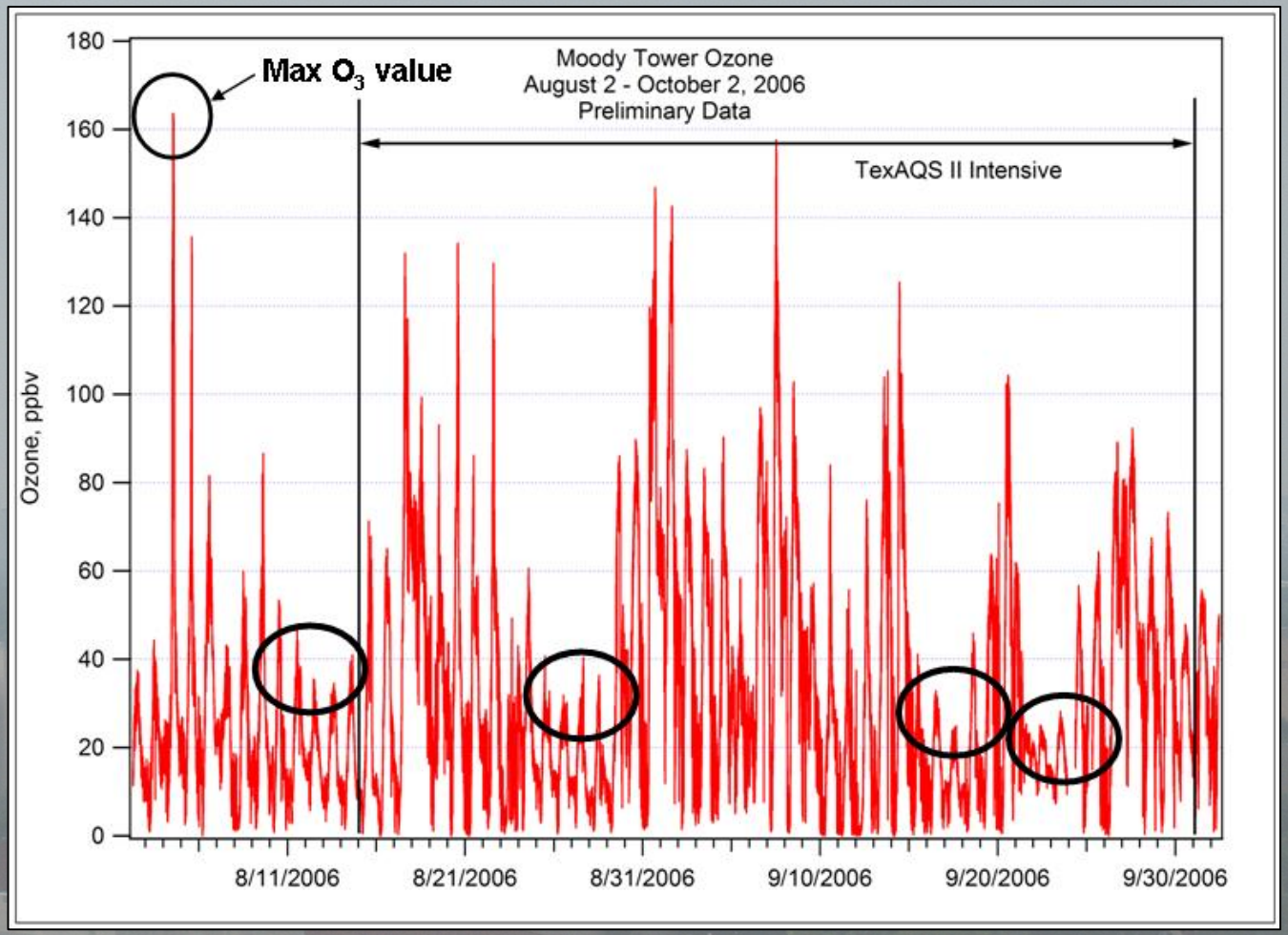


Daytime: generally good agreement.
Nighttime: At night Moody tower in-situ observations often fall between the lower and middle light-path DOAS mixing ratios.

Background O_3 vs high O_3 plumes

PIs:
B. Lefer/
B. Rappenglueck
(UH)

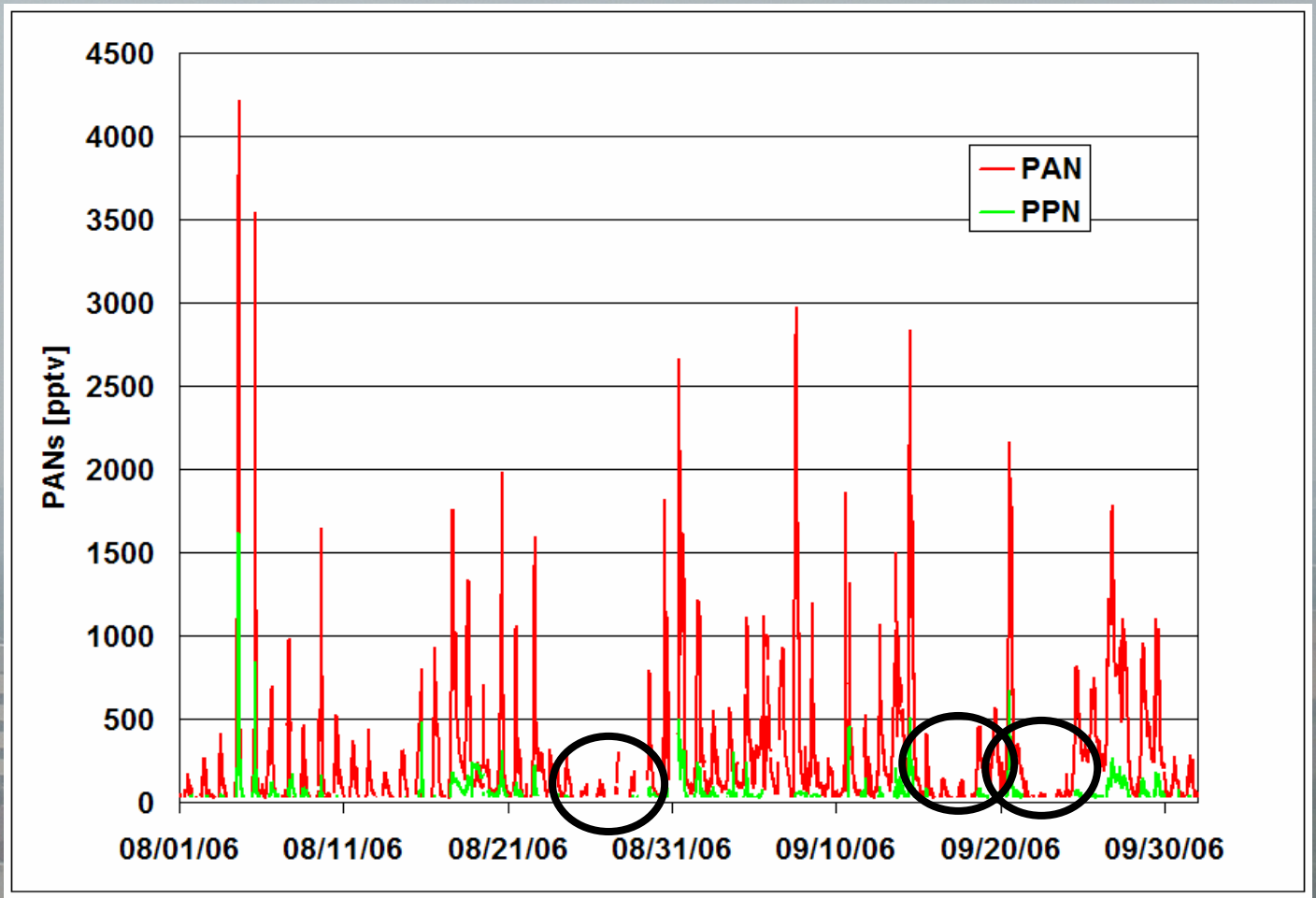


Large variability:

- low background values (30 ppb): air masses from SE (Gulf of Mexico)
- high background values (up to 80 ppb): continental air masses
- Very high values (160 ppb): Ship Channel

Background PAN vs high PAN plumes

PI:
B. Rappenglueck
(UH)

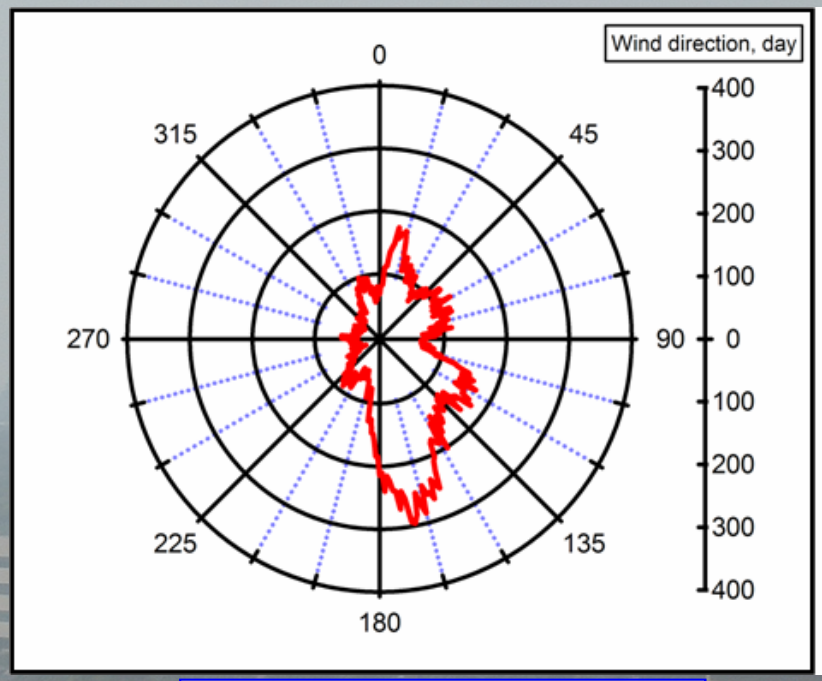


Large variability:

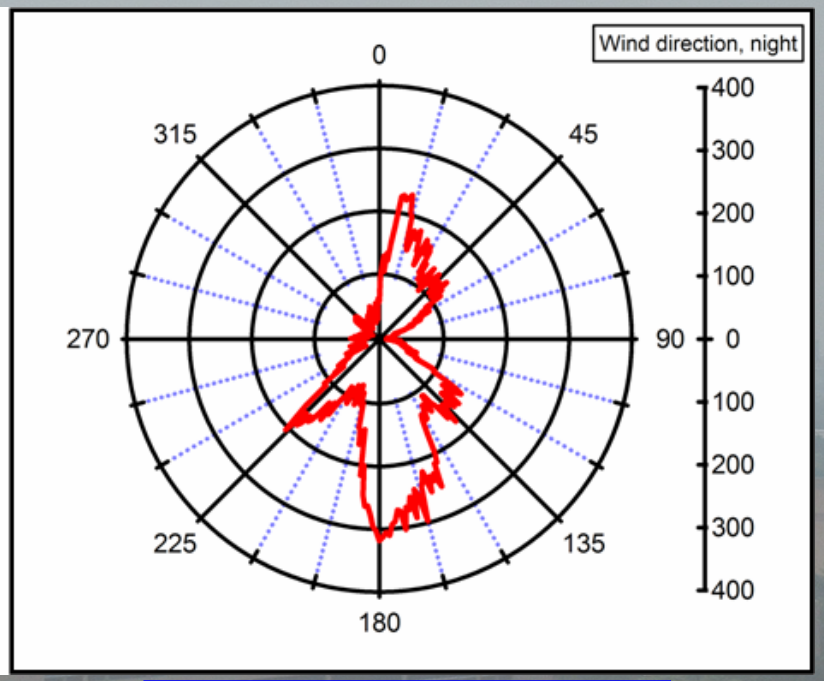
- low background values (<30 ppt): air masses from SE (Gulf of Mexico)
- high values (4.2 ppb): Ship Channel

Wind Direction

PIs:
B. Lefer/
B. Rappenglueck
(UH)



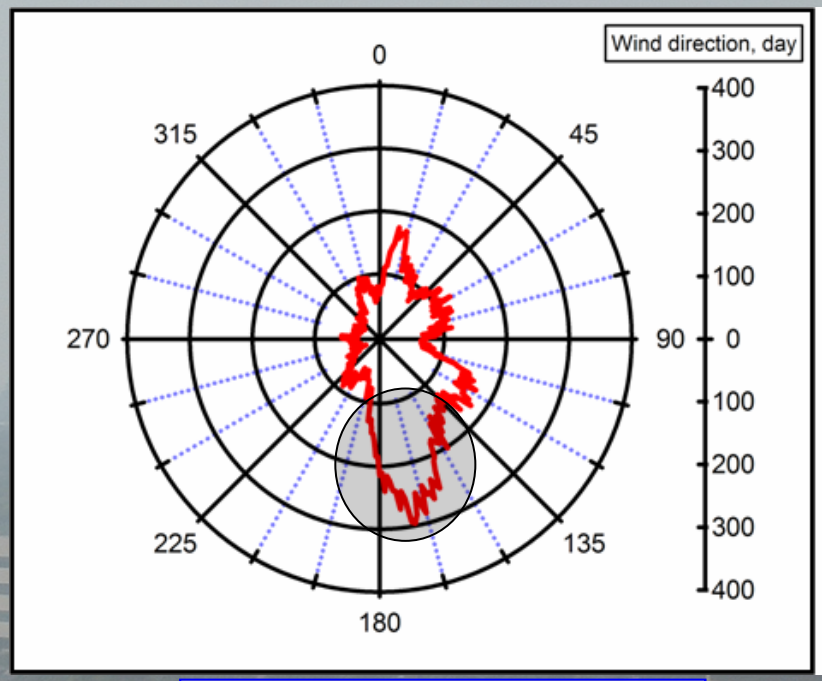
9:00 am – 9:00 pm (LT)



9:00 pm – 9:00 am (LT)

Wind Direction

PIs:
B. Lefer/
B. Rappenglueck
(UH)



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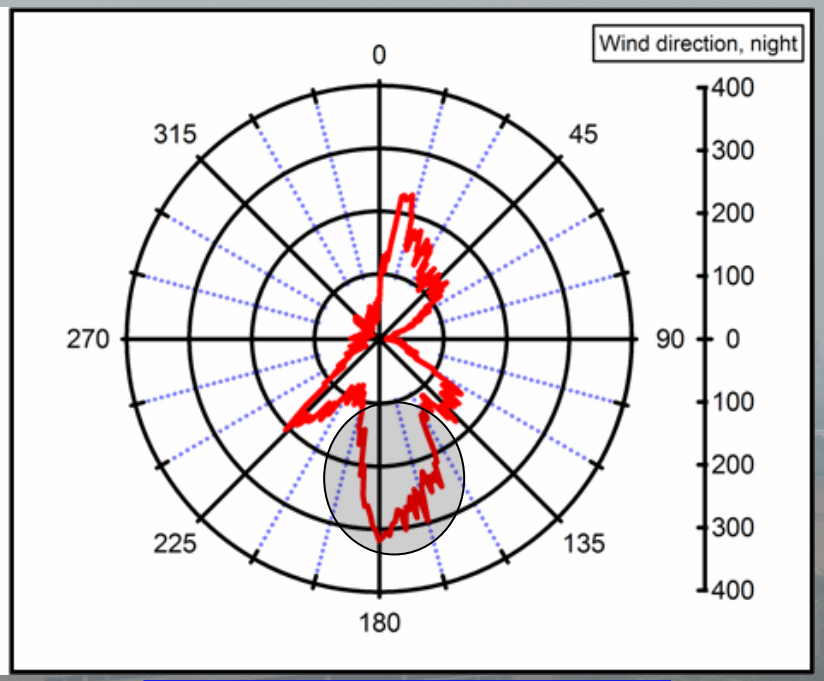
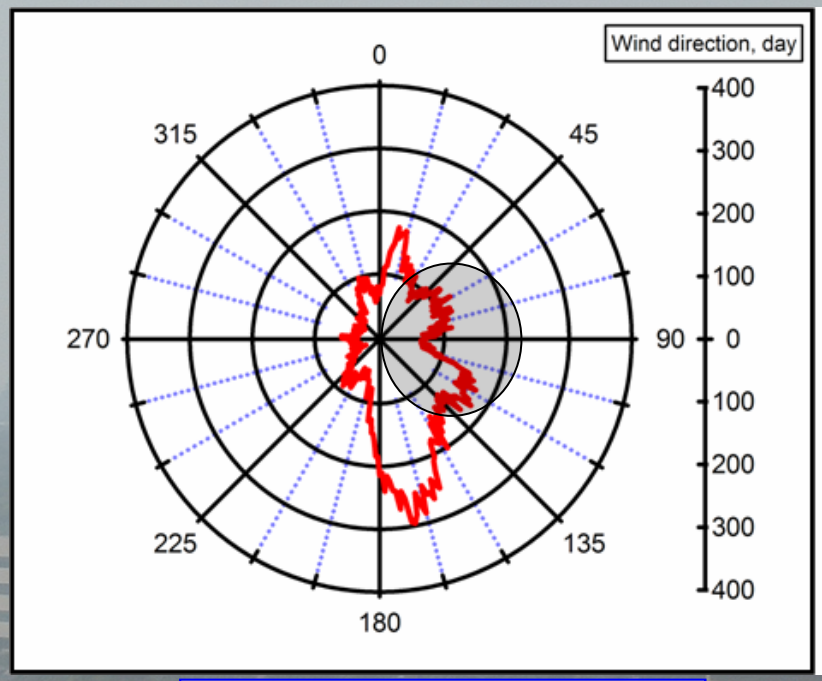


9:00 pm – 9:00 am (LT)

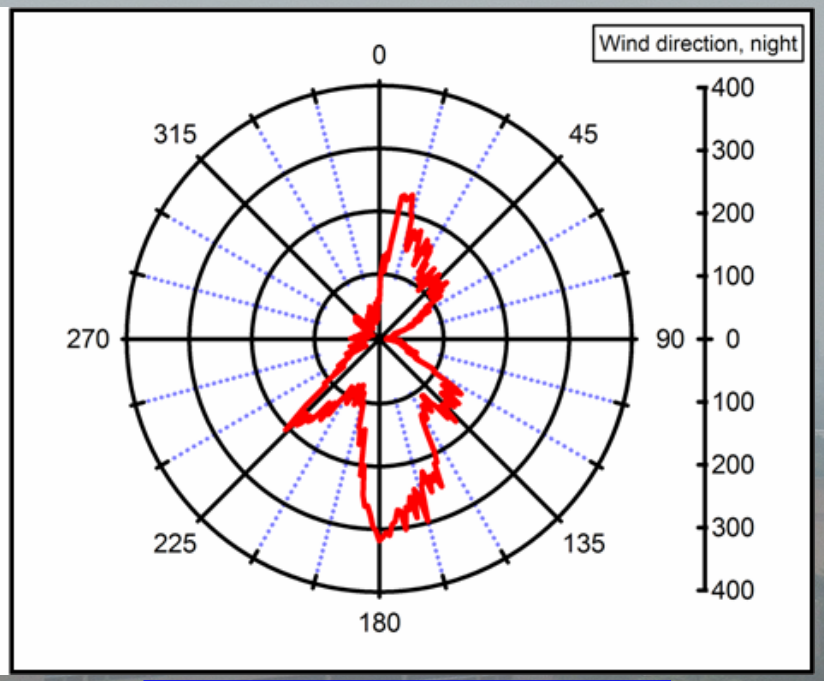
Daytime and nighttime: S/SW wind directions present

Wind Direction

PIs:
B. Lefer/
B. Rappenglueck
(UH)



9:00 am – 9:00 pm (LT)

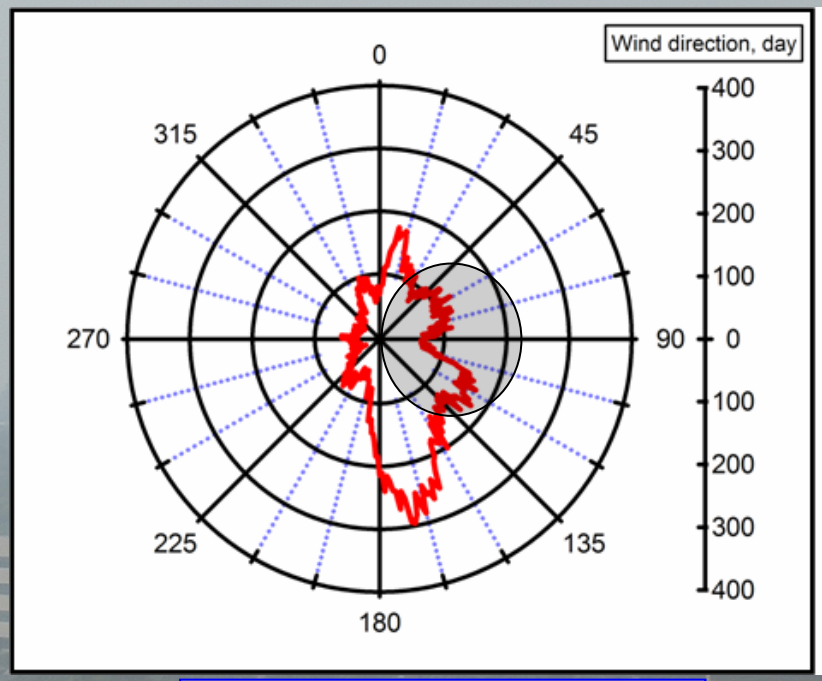


9:00 pm – 9:00 am (LT)

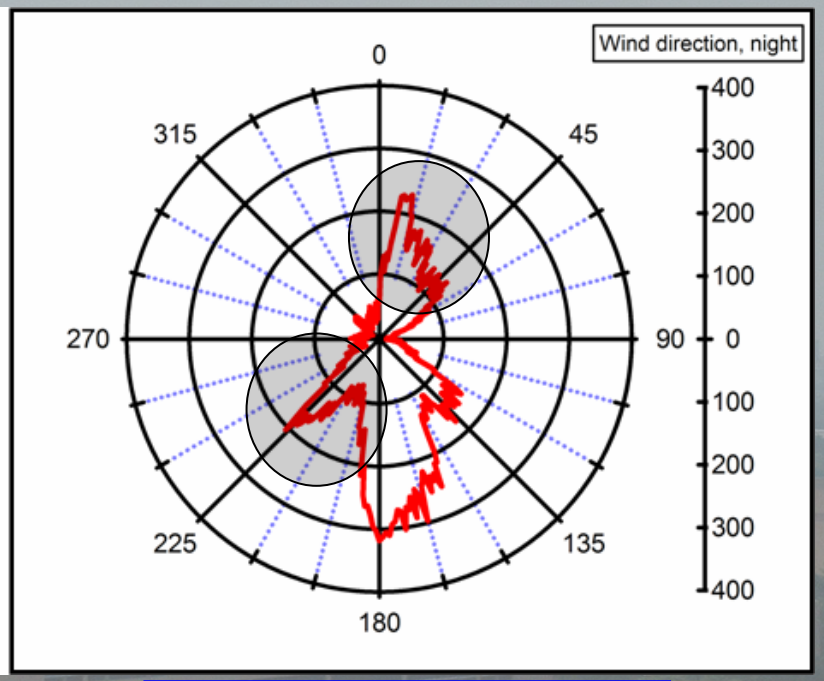
Daytime: higher frequency of E directions

Wind Direction

PIs:
B. Lefer/
B. Rappenglueck
(UH)



9:00 am – 9:00 pm (LT)

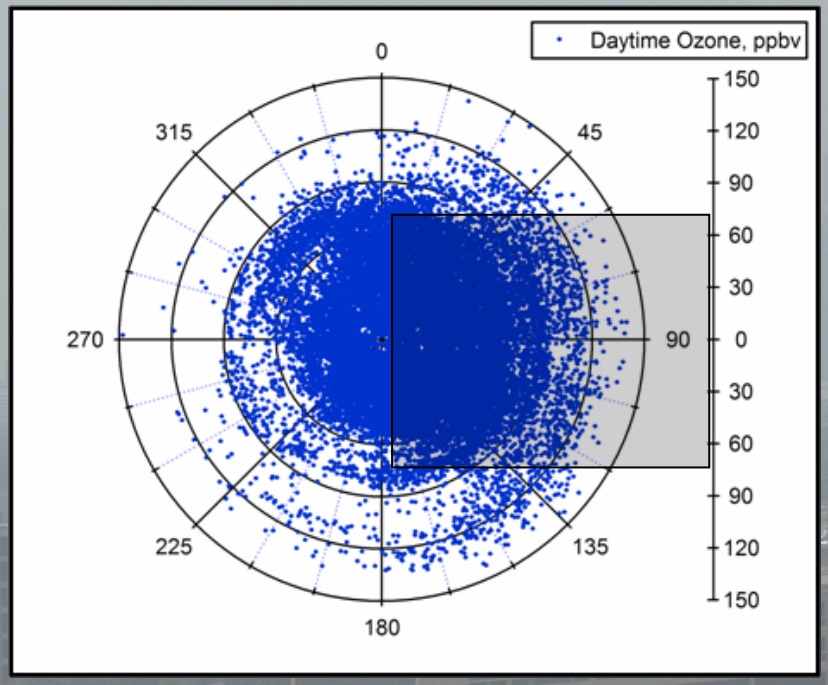


9:00 pm – 9:00 am (LT)

Daytime: higher frequency of E directions
Nighttime: SW (and NE) wind directions present

Daytime O_3 vs Wind Direction

PIs:
B. Lefer/
B. Rappenglueck
(UH)

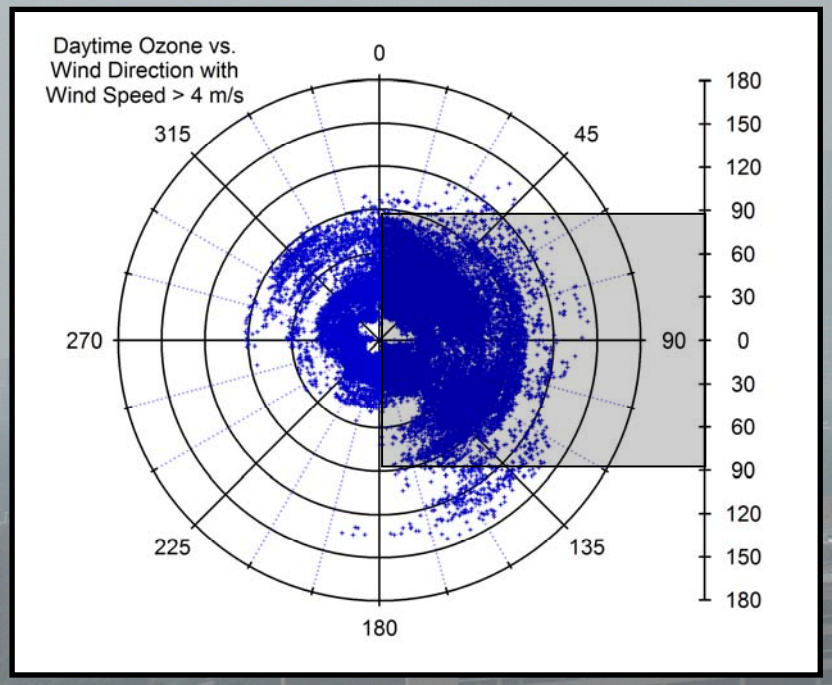


9:00 am – 9:00 pm (LT)

High O_3 values associated with E flow conditions

Daytime O_3 vs Wind Direction (WS > 4 m/s)

PIs:
B. Lefer/
B. Rappenglueck
(UH)

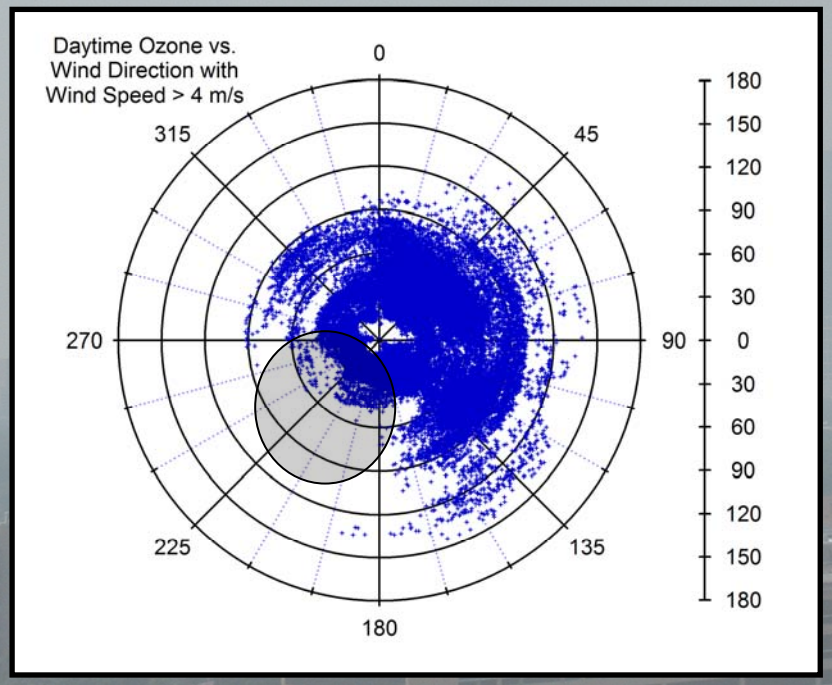


9:00 am – 9:00 pm (LT)

Even under higher wind speed conditions still high O_3 values associated with E flow conditions.

Daytime O_3 vs Wind Direction (WS > 4 m/s)

PIs:
B. Lefer/
B. Rappenglueck
(UH)

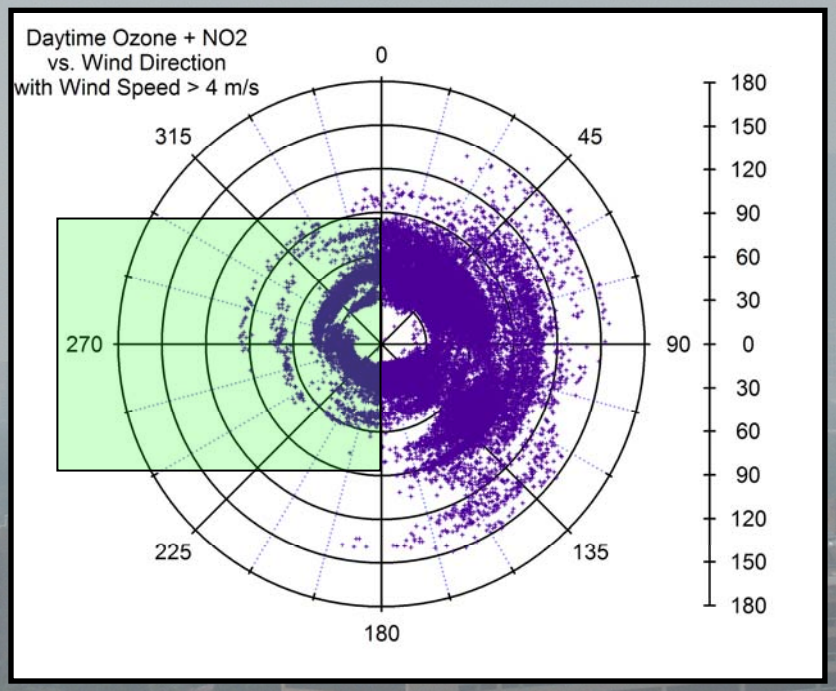


9:00 am – 9:00 pm (LT)

Under higher wind speed conditions low background O_3 values (close to 30 ppbv) are observed at SW flow (marine) conditions in coincidence with low level O_3 days in O_3 time series.

Daytime O_x vs Wind Direction (WS > 4 m/s)

PIs:
B. Lefer/
B. Rappenglueck
(UH)

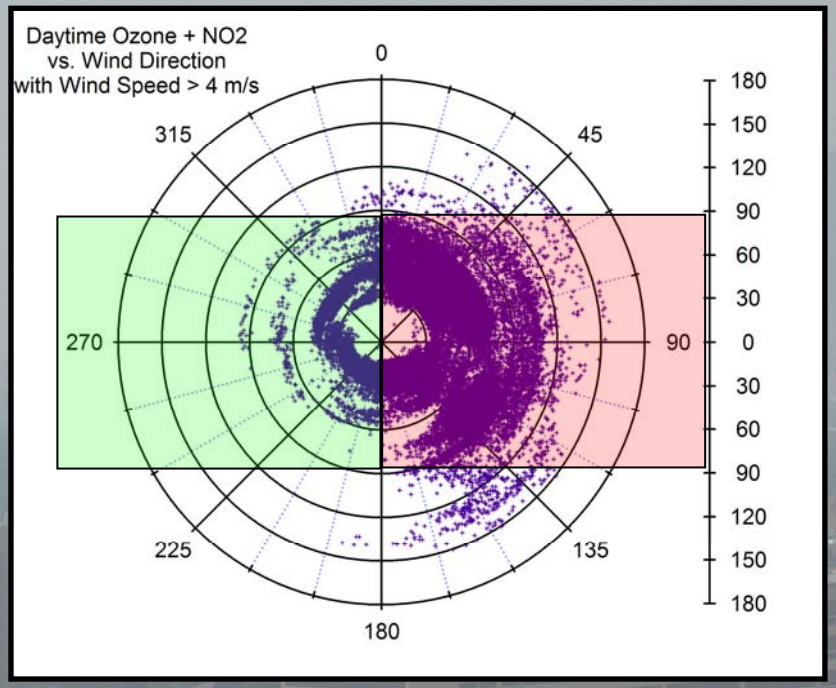


9:00 am – 9:00 pm (LT)

Low O_x associated with W flows

Daytime O_x vs Wind Direction (WS > 4 m/s)

PIs:
B. Lefer/
B. Rappenglueck
(UH)

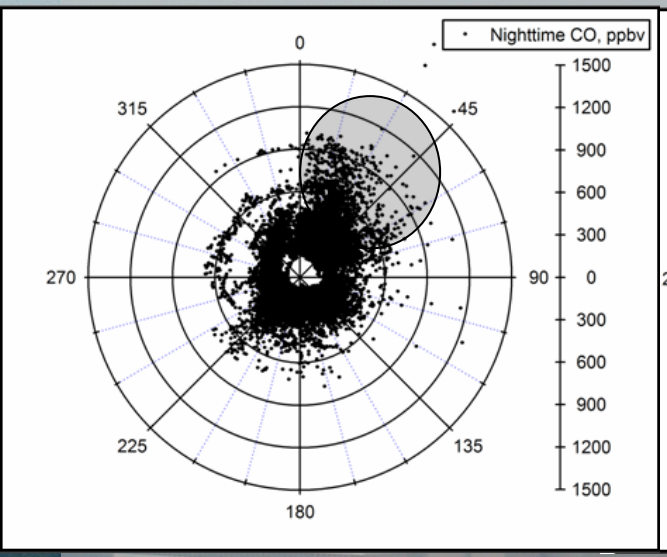


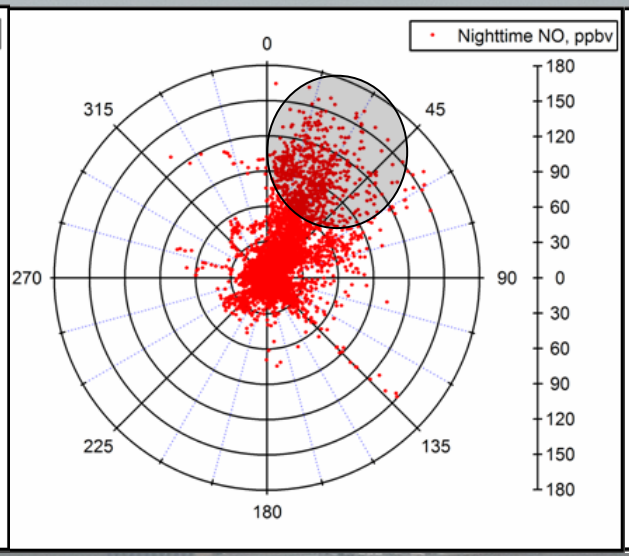
9:00 am – 9:00 pm (LT)

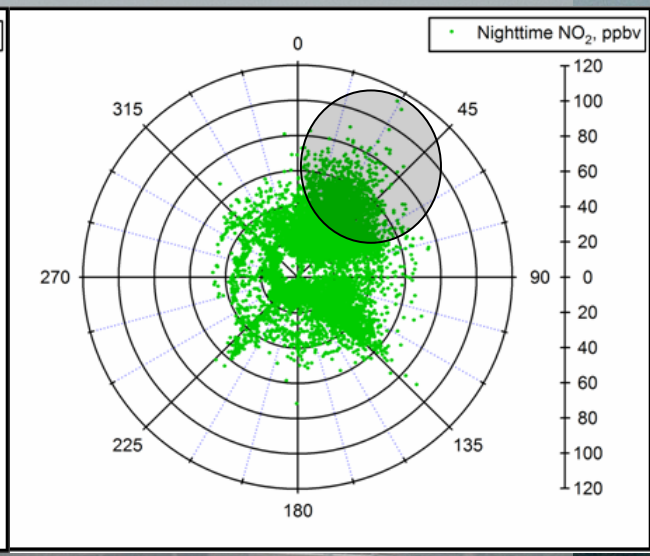
Low O_x associated with W flows,
high O_x associated with E flow conditions

CO, NO, NO_2 vs Wind Direction (Nighttime)

PIs:
B. Lefer/
B. Rappenglueck
(UH)





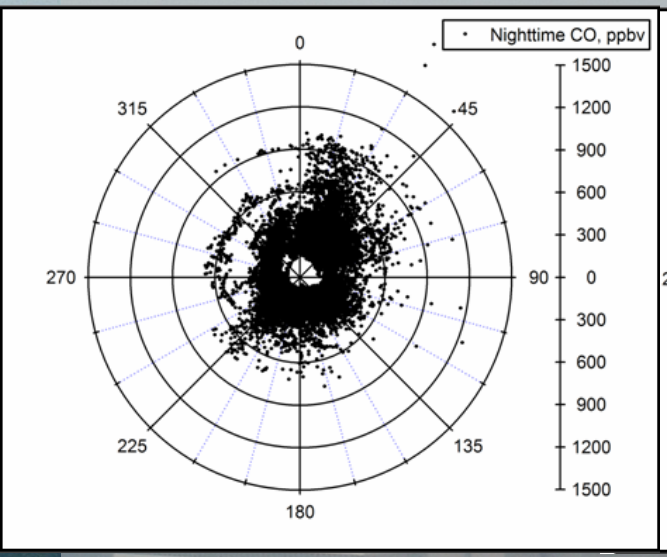


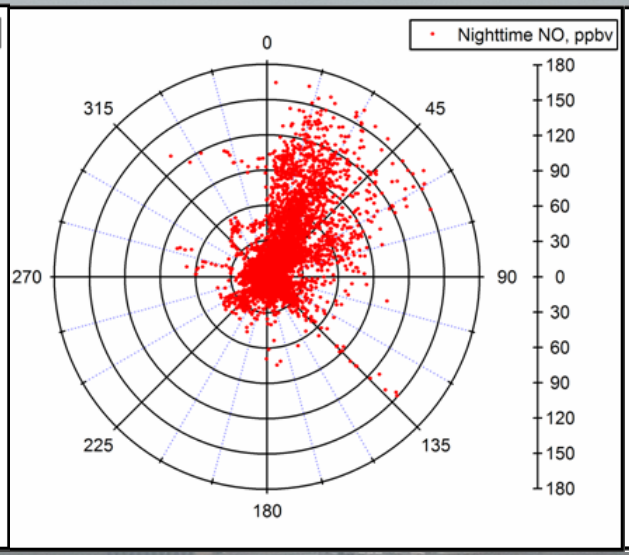
9:00 pm – 9:00 am (LT)

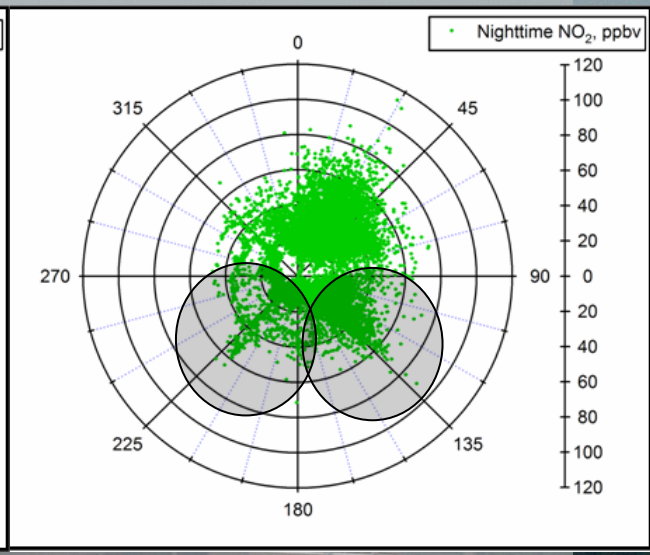
Maximum levels usually under NNE wind flows

CO, NO, NO_2 vs Wind Direction (Nighttime)

PIs:
B. Lefer/
B. Rappenglueck
(UH)





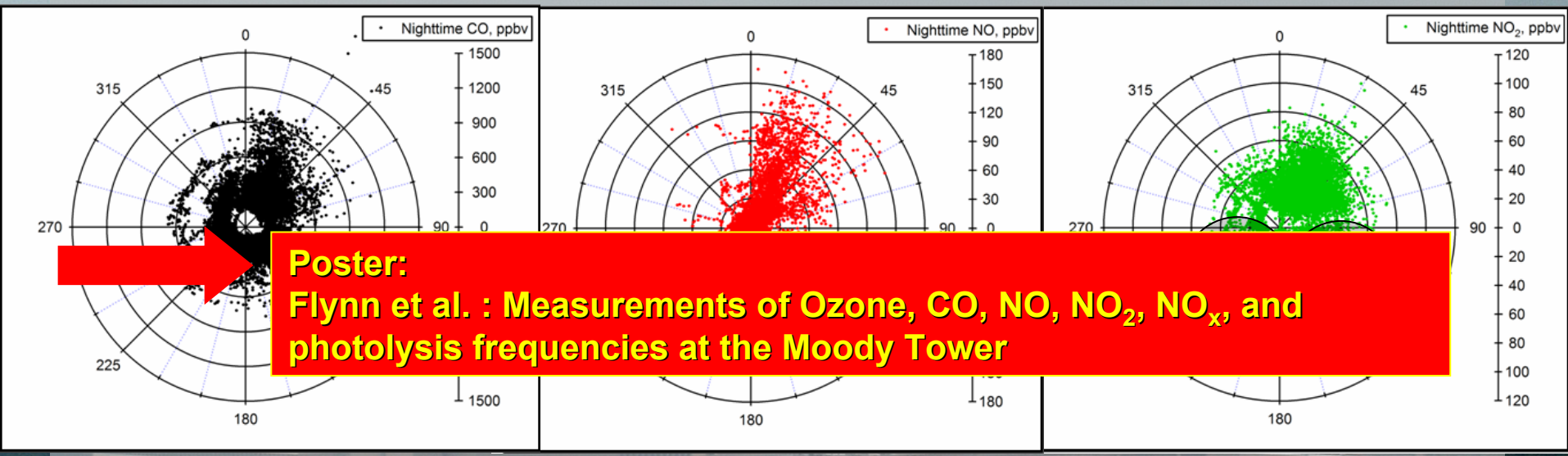


9:00 pm – 9:00 am (LT)

Some enhancement of NO_2 under SW (Parrish power plant) and SE (Texas City) flows

CO, NO, NO_2 vs Wind Direction (Nighttime)

PIs:
B. Lefer/
B. Rappenglueck
(UH)



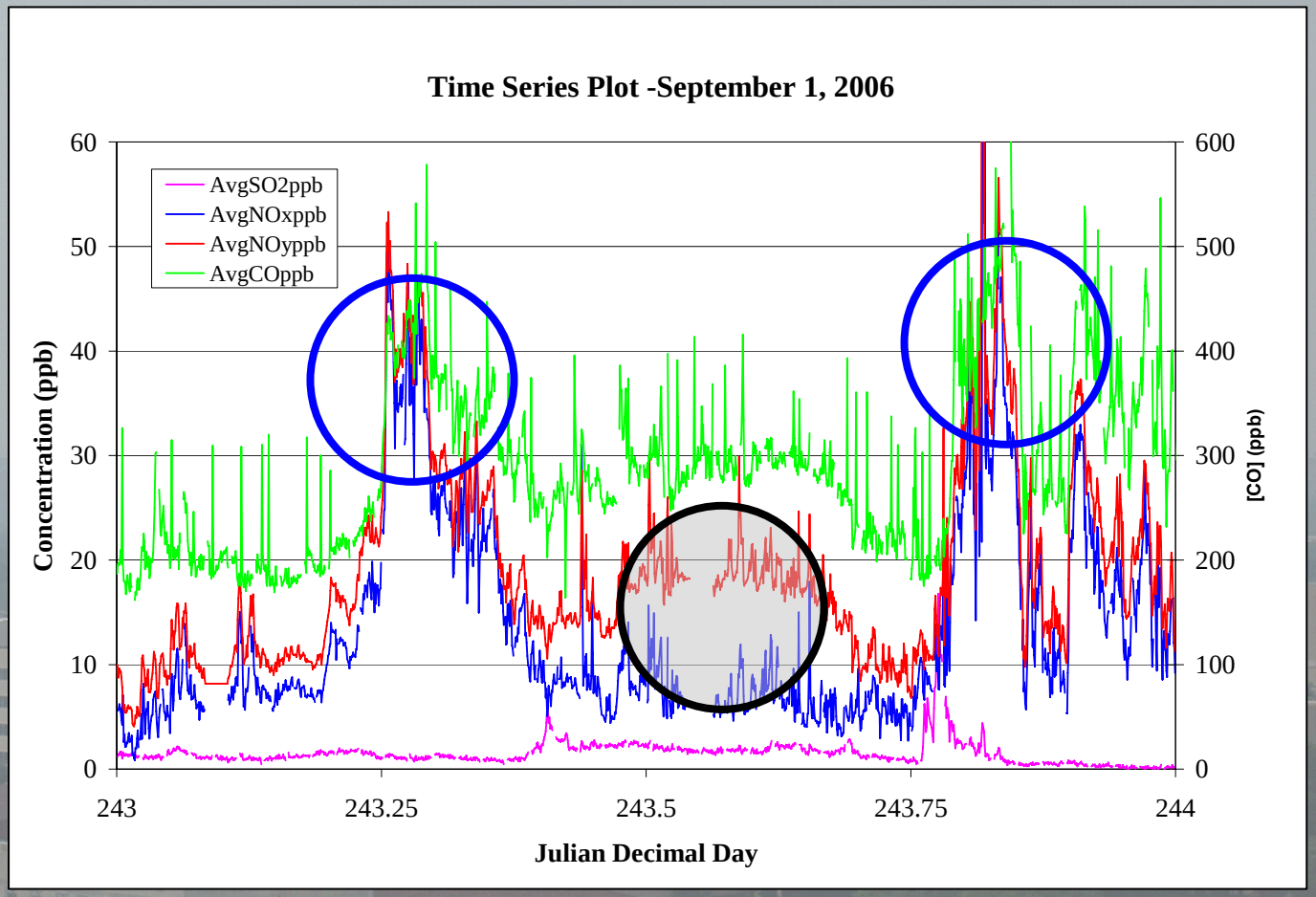
Poster:
Flynn et al. : Measurements of Ozone, CO, NO, NO_2, NO_x, and photolysis frequencies at the Moody Tower

9:00 pm – 9:00 am (LT)

Some enhancement of NO_2 under SW (Parrish power plant) and SE (Texas City) flows

NO_y

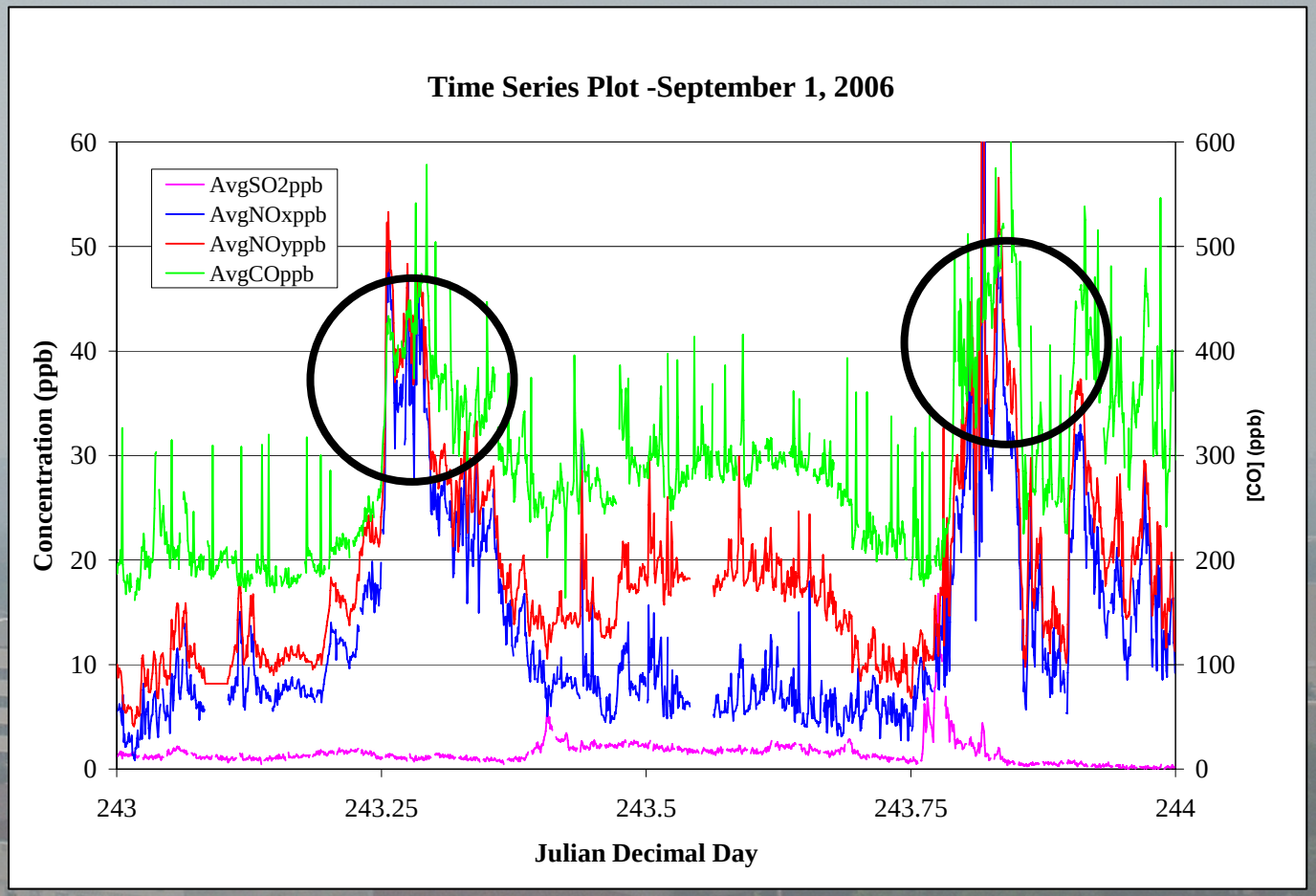
PI:
W. Luke (NOAA)



NO_y fractions:
NO_x during rush hour NO_z during mid day (HNO_3?)

NO_y

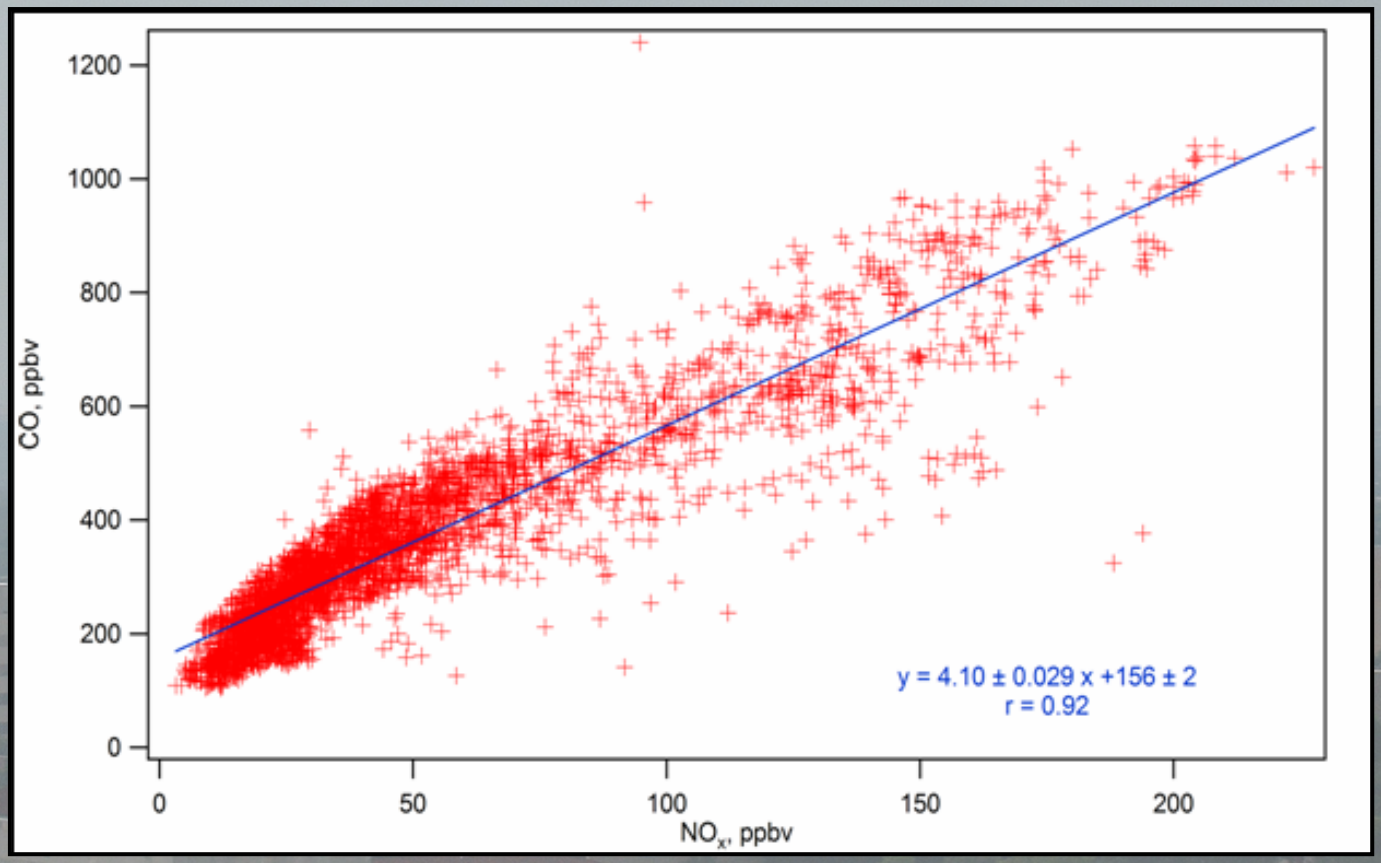
PI:
W. Luke (NOAA)



Rush hour: close correlation between NO_y and CO

Rush Hour CO/NO_x Ratio

PIs:
B. Lefer/
B. Rappenglueck
(UH)

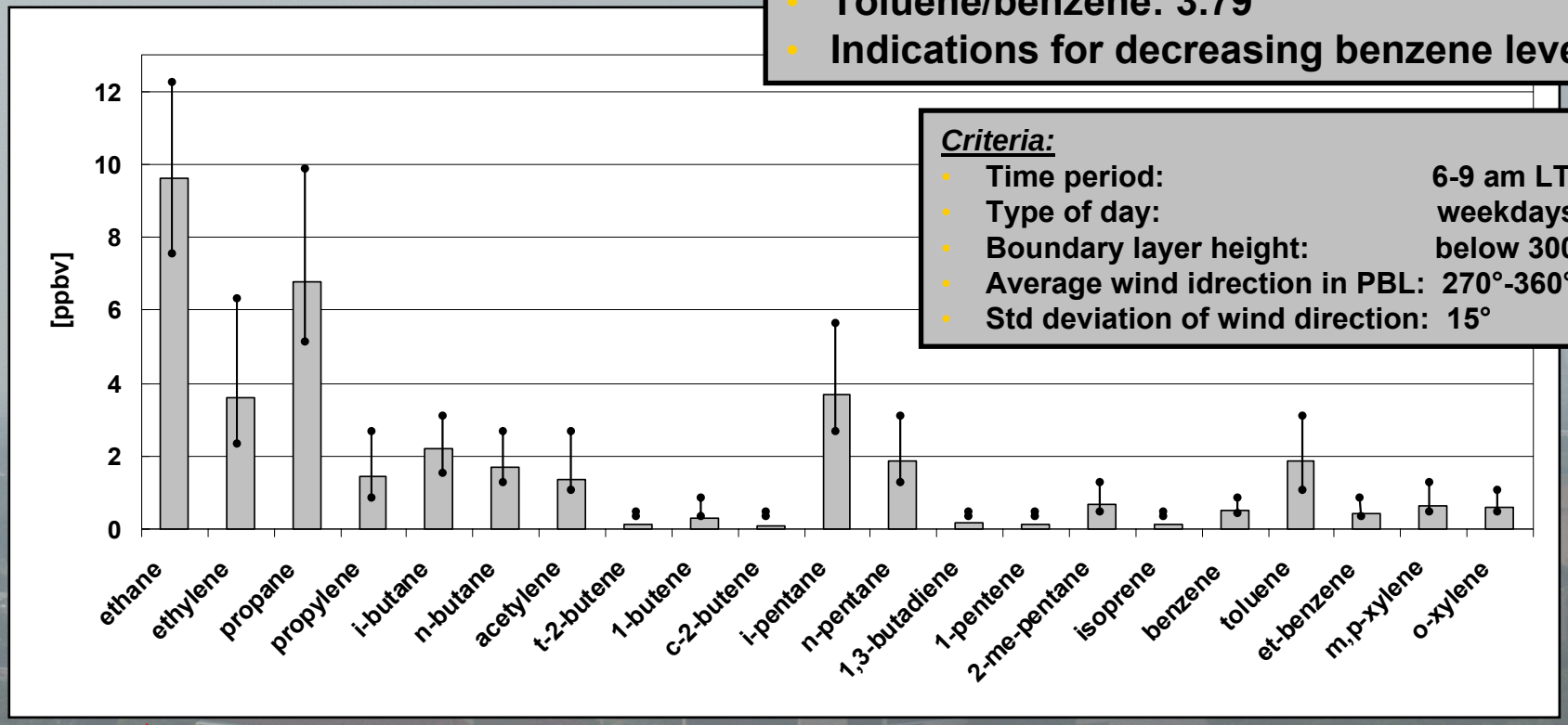


Morning rush hour CO/NO_x ratio is 4.10 ± 0.029 with a background CO value of 156 ± 2 ppbv.

Traffic VOC speciation (GC/FID)

PI:
B. Rappenglueck
(UH)

- Toluene/benzene: 3.79
- Indications for decreasing benzene levels



Criteria:

- Time period: 6-9 am LT
- Type of day: weekdays
- Boundary layer height: below 300 m
- Average wind idrection in PBL: 270°-360°
- Std deviation of wind direction: 15°

Rush hour: high correlation between aromatic compounds, acetylene, ethylene and propylene.
Poor correlations with alkanes vs other NMHCs
Isoprene also present

PCA Analysis (GC/FID)

PI:
B. Rappenglueck
(UH)

Current analysis:
C_2-C_8 VOCs (9/16-9/30)

86% of total variance explained by 5 factors

F1:

Industrial processes as well as evaporation.

Alkanes, several alkenes, some benzene

	F1	F2	F3	F4	F5
CO		0.85			
ethane	0.84				
ethylene	0.61	0.50			
acetylene		0.82			
propane	0.82				
propylene	0.67				
i-butane	0.93				
n-butane	0.92				
t-2-butene			0.89		
1-butene	0.53		0.53		
i-butene				0.82	
c-2-butene			0.81		
cyclopentane	0.76				
i-pentane	0.85				
n-pentane	0.64			0.58	
t-2-pentene		0.59	0.70		
2-methyl-1-butene			0.78		
1-pentene		0.61	0.58		
c-2-pentene		0.57	0.69		
2,3-dimethylbutane	0.58	0.58			
2-methylpentane	0.70	0.54			
3-methylpentane	0.68	0.57			
isoprene					-0.91
benzene	0.53				
toluene		0.82			
ethylbenzene		0.77			
m,p-xylene		0.84			
o-xylene		0.87			
1,3,5-trimethylbenzene		0.82			

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

PCA Analysis (GC/FID)

PI:
B. Rappenglueck
(UH)

Current analysis:
C_2-C_8 VOCs (9/16-9/30)

86% of total variance explained by 5 factors

F2:

Combustion processes (e.g. traffic).

Aromatics, acetylene, CO

	F1	F2	F3	F4	F5
CO		0.85			
ethane	0.84				
ethylene	0.61	0.50			
acetylene		0.82			
propane	0.82				
propylene	0.67				
i-butane	0.93				
n-butane	0.92				
t-2-butene			0.89		
1-butene	0.53		0.53		
i-butene				0.82	
c-2-butene			0.81		
cyclopentane	0.76				
i-pentane	0.85				
n-pentane	0.64			0.58	
t-2-pentene		0.59	0.70		
2-methyl-1-butene			0.78		
1-pentene		0.61	0.58		
c-2-pentene		0.57	0.69		
2,3-dimethylbutane	0.58	0.58			
2-methylpentane	0.70	0.54			
3-methylpentane	0.68	0.57			
isoprene					-0.91
benzene	0.53				
toluene		0.82			
ethylbenzene		0.77			
m,p-xylene		0.84			
o-xylene		0.87			
1,3,5-trimethylbenzene		0.82			

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

PCA Analysis (GC/FID)

PI:
B. Rappenglueck
(UH)

Current analysis:
C_2-C_8 VOCs (9/16-9/30)

86% of total variance explained by 5 factors

F3:

Industrial emissions

C_4-C_5 alkenes

	F1	F2	F3	F4	F5
CO		0.85			
ethane	0.84				
ethylene	0.61	0.50			
acetylene		0.82			
propane	0.82				
propylene	0.67				
i-butane	0.93				
n-butane	0.92				
t-2-butene			0.89		
1-butene	0.53		0.53		
i-butene				0.82	
c-2-butene			0.81		
cyclopentane	0.76				
i-pentane	0.85				
n-pentane	0.64			0.58	
t-2-pentene		0.59	0.70		
2-methyl-1-butene			0.78		
1-pentene		0.61	0.58		
c-2-pentene		0.57	0.69		
2,3-dimethylbutane	0.58	0.58			
2-methylpentane	0.70	0.54			
3-methylpentane	0.68	0.57			
isoprene					-0.91
benzene	0.53				
toluene		0.82			
ethylbenzene		0.77			
m,p-xylene		0.84			
o-xylene		0.87			
1,3,5-trimethylbenzene		0.82			

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

PCA Analysis (GC/FID)

PI:
B. Rappenglueck
(UH)

Current analysis:
C_2-C_8 VOCs (9/16-9/30)

86% of total variance explained by 5 factors

F4:

Source yet tbd (LPG?)

i-butene, n-pentane

	F1	F2	F3	F4	F5
CO		0.85			
ethane	0.84				
ethylene	0.61	0.50			
acetylene		0.82			
propane	0.82				
propylene	0.67				
i-butane	0.93				
n-butane	0.92				
t-2-butene			0.89		
1-butene	0.53		0.53		
i-butene				0.82	
c-2-butene			0.81		
cyclopentane	0.76				
i-pentane	0.85				
n-pentane	0.64			0.58	
t-2-pentene		0.59	0.70		
2-methyl-1-butene			0.78		
1-pentene		0.61	0.58		
c-2-pentene		0.57	0.69		
2,3-dimethylbutane	0.58	0.58			
2-methylpentane	0.70	0.54			
3-methylpentane	0.68	0.57			
isoprene					-0.91
benzene	0.53				
toluene		0.82			
ethylbenzene		0.77			
m,p-xylene		0.84			
o-xylene		0.87			
1,3,5-trimethylbenzene		0.82			

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

PCA Analysis (GC/FID)

PI:
B. Rappenglueck
(UH)

Current analysis:
C_2-C_8 VOCs (9/16-9/30)

86% of total variance explained by 5 factors

F5:

Biogenic sources

isoprene

	F1	F2	F3	F4	F5
CO		0.85			
ethane	0.84				
ethylene	0.61	0.50			
acetylene		0.82			
propane	0.82				
propylene	0.67				
i-butane	0.93				
n-butane	0.92				
t-2-butene			0.89		
1-butene	0.53		0.53		
i-butene				0.82	
c-2-butene			0.81		
cyclopentane	0.76				
i-pentane	0.85				
n-pentane	0.64			0.58	
t-2-pentene		0.59	0.70		
2-methyl-1-butene			0.78		
1-pentene		0.61	0.58		
c-2-pentene		0.57	0.69		
2,3-dimethylbutane	0.58	0.58			
2-methylpentane	0.70	0.54			
3-methylpentane	0.68	0.57			
isoprene					-0.91
benzene	0.53				
toluene		0.82			
ethylbenzene		0.77			
m,p-xylene		0.84			
o-xylene		0.87			
1,3,5-trimethylbenzene		0.82			

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

PCA Analysis (GC/FID)

PI:
B. Rappenglueck
(UH)

Current analysis:
C_2-C_8 VOCs (9/16-9/30)

86% of total variance explained by 5 factors

F5:

Biogeni

isoprene

Poster:
Leuchner et al.: Measurements of VOC, PAN, Formaldehyde, and Hydrogen Peroxide at the Moody Tower Site, Houston

	F1	F2	F3	F4	F5
CO		0.85			
ethane	0.84				
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o-xylene		0.87			
1,3,5-trimethylbenzene		0.82			

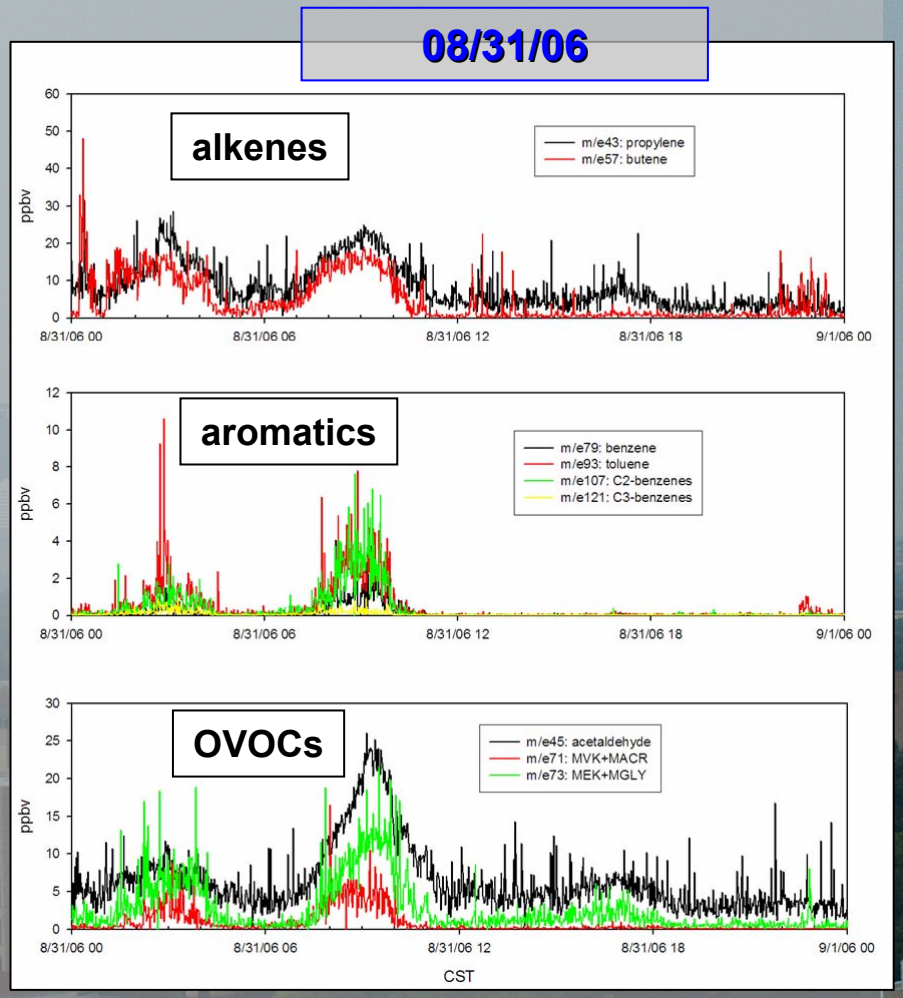
Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

VOCs (PTR-MS)

PI:
R. Zhang
(Texas A&M)

More than 20 VOCs.

Measurement periods:
08/17-09/13
10/01-10/15



Time series of alkenes, aromatics, and OVOCS.

VOCs (PTR-MS)

PI:
R. Zhang
(Texas A&M)

More than 20 VOCs.

Measurement periods:
08/17-09/13
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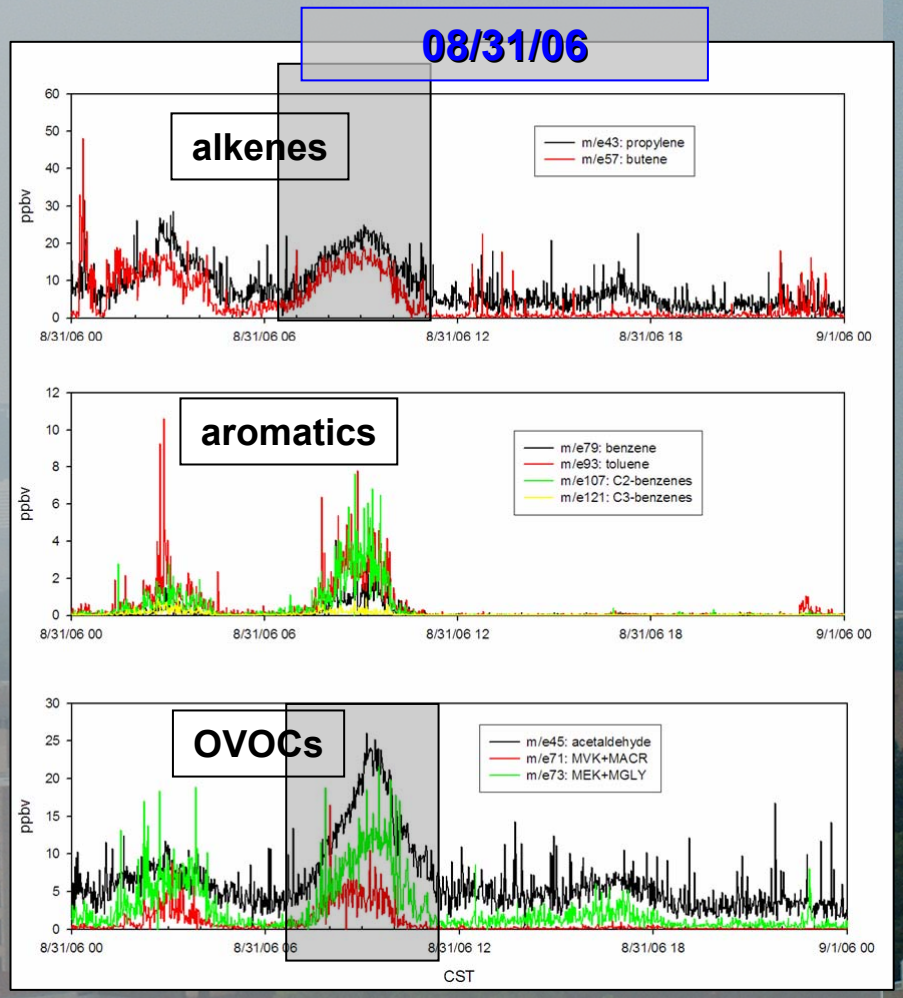


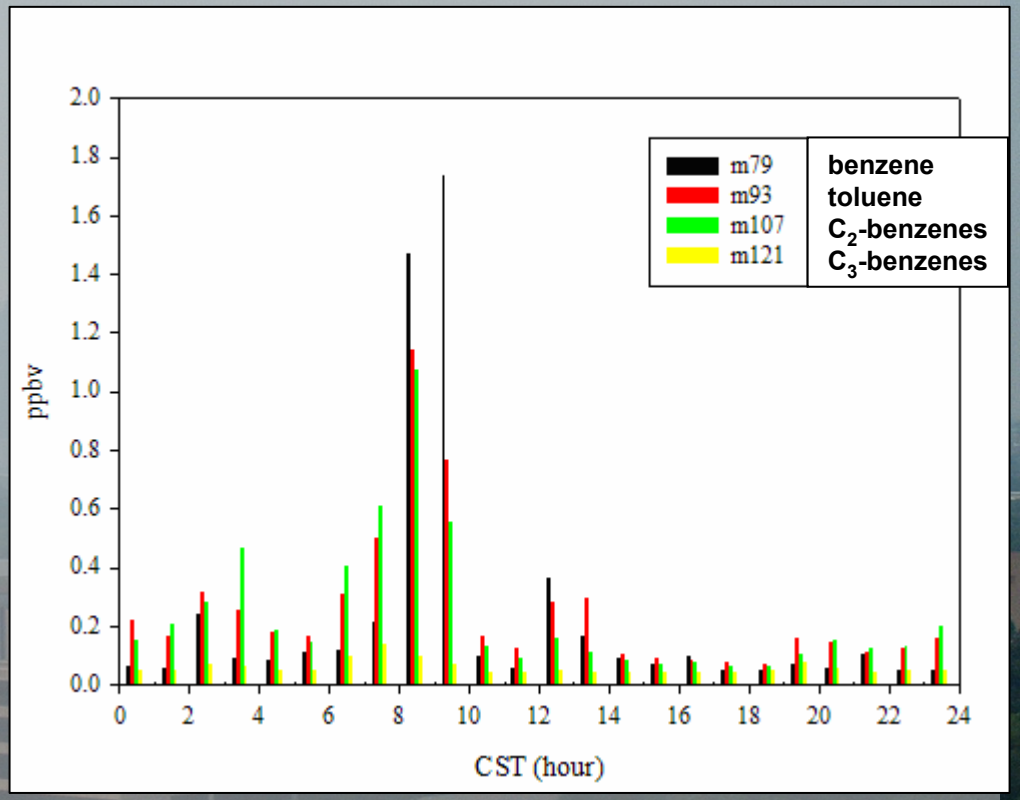
Time series of alkenes, aromatics, and OVOCS.
High values of propene, butenes, and OVOCs in the morning.

VOCs (PTR-MS)

PI:
R. Zhang
(Texas A&M)

More than 20 VOCs.

Here:
Hourly averaged aromatic VOCs measured from 08/17-09/01.



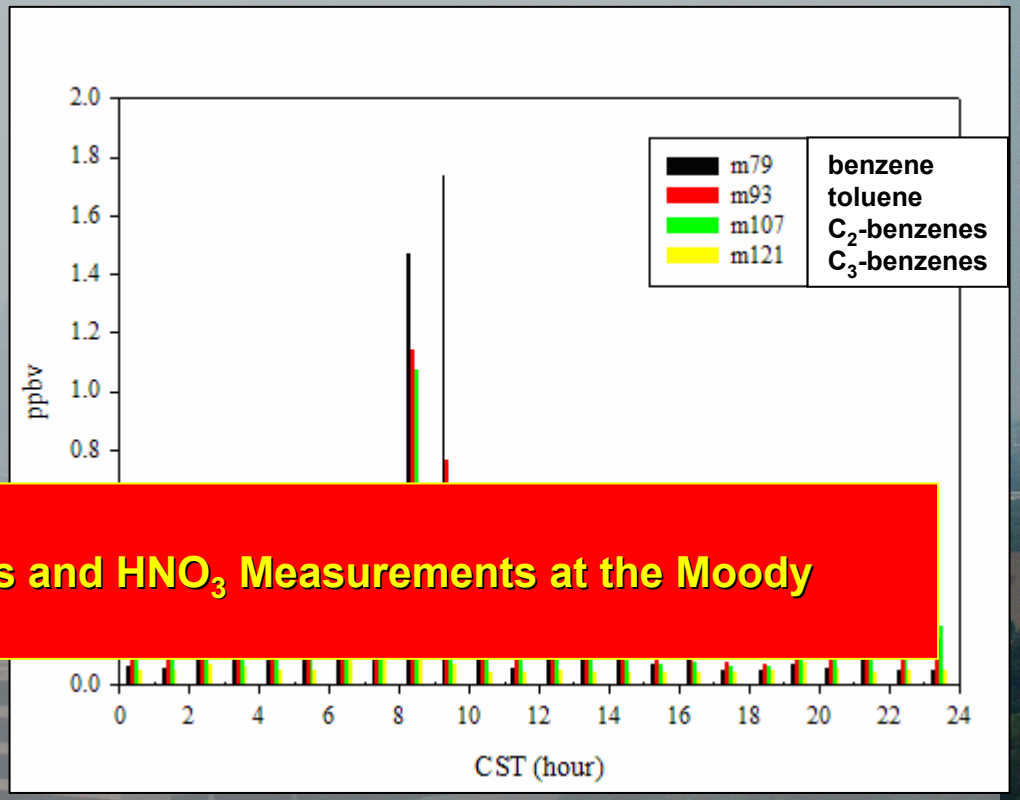
Unlike alkenes, aromatic VOCs were more correlated with the traffic conditions (e.g. peak time concurred with the morning rush hour).

VOCs (PTR-MS)

PI:
R. Zhang
(Texas A&M)

More than 20 VOCs.

Here:
Hourly averaged aromatic VOCs measured from 08/17-09/01.

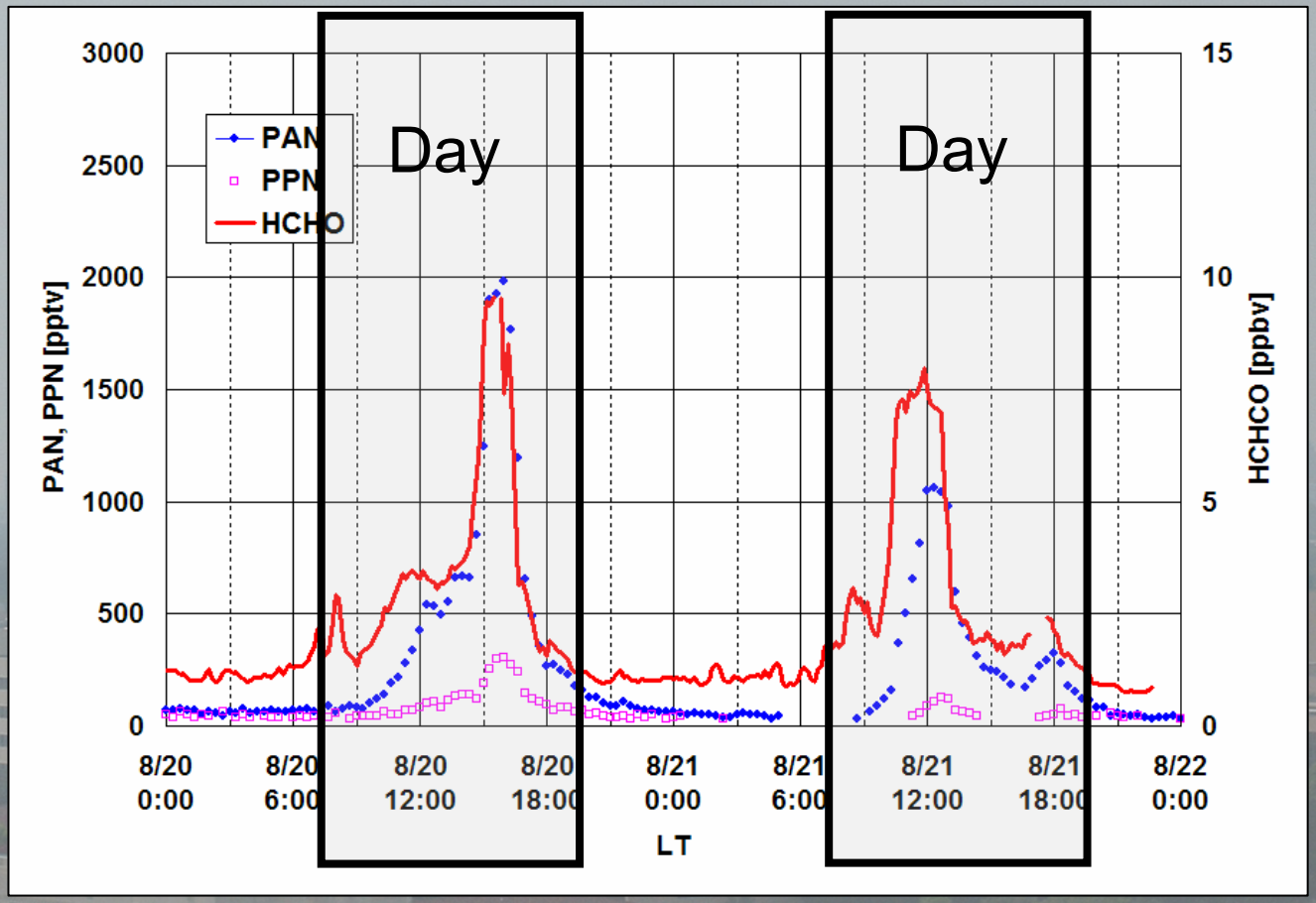


Poster:
Zheng and Zhang: VOCs and HNO_3 Measurements at the Moody Tower

Unlike alkenes, aromatic VOCs were more correlated with the traffic conditions (e.g. peak time concurred with the morning rush hour).

Formaldehyde, PANs

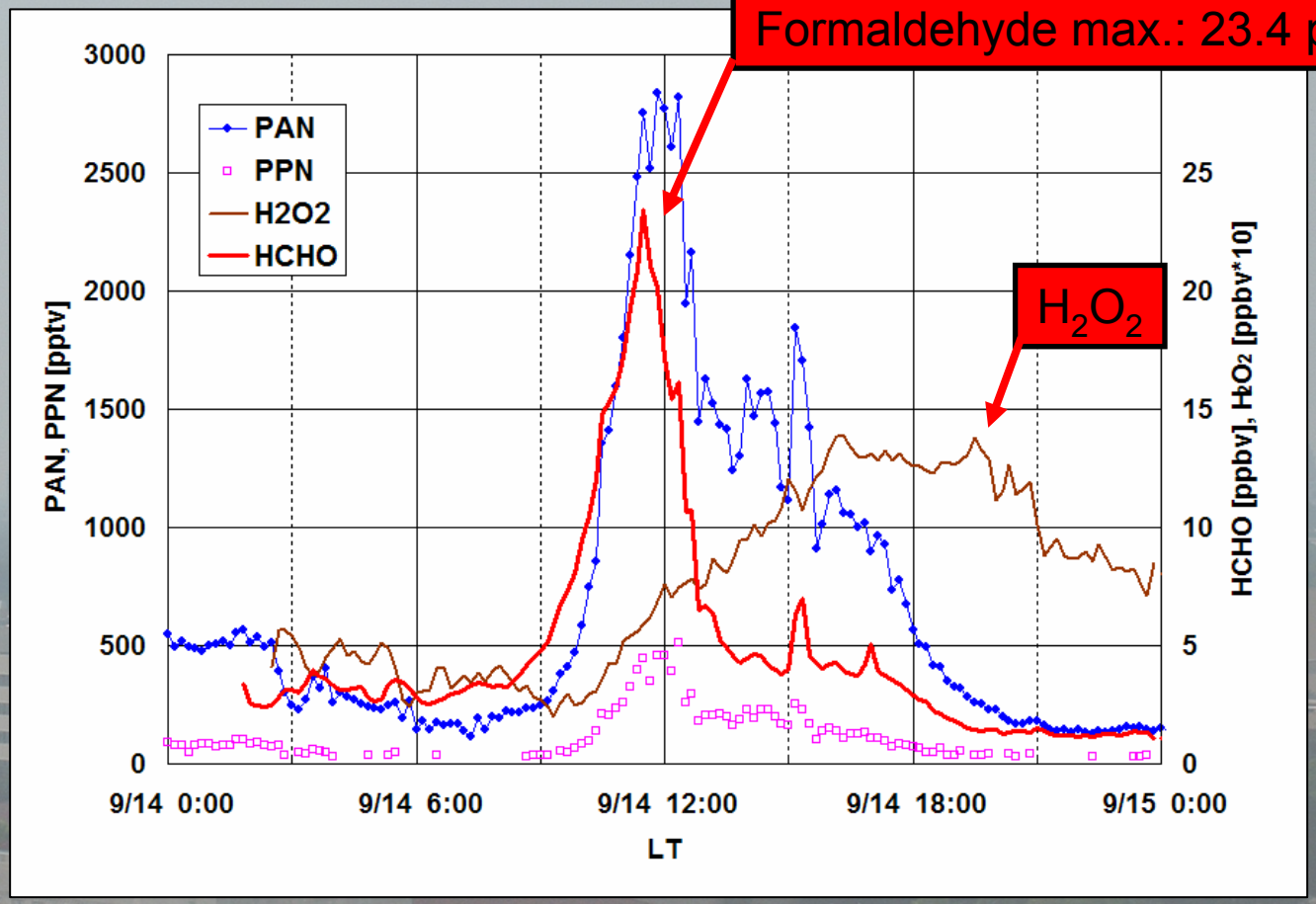
PI:
B. Rappenglueck
(UH)



Daytime: Secondary formaldehyde coincides with PAN and PPN

Formaldehyde, PANs, H_2O_2

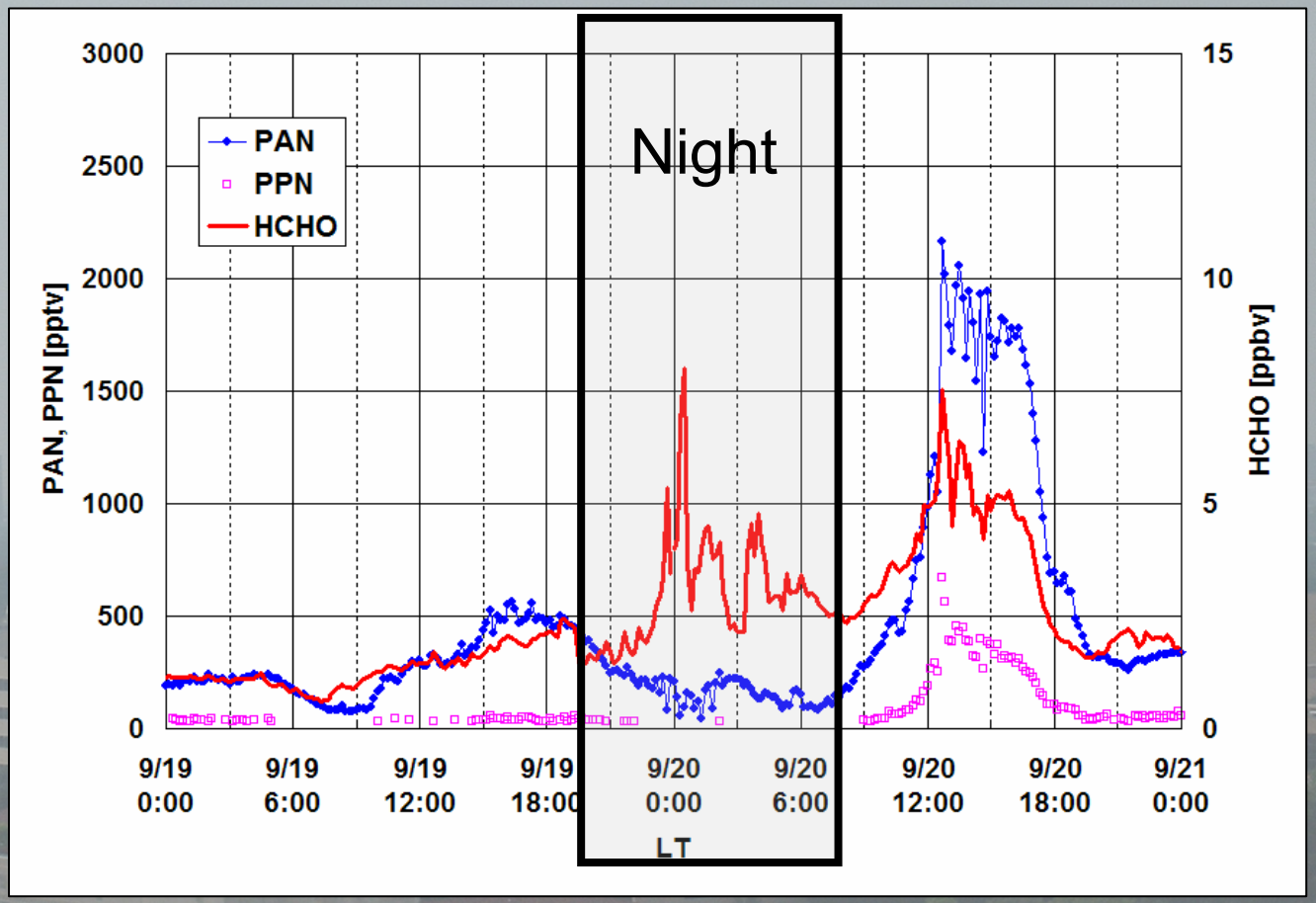
PI:
B. Rappenglueck
(UH)



Daytime: Secondary formaldehyde coincides with PAN and PPN
H_2O_2 peaks in the late afternoon/early evening

Formaldehyde, PANs

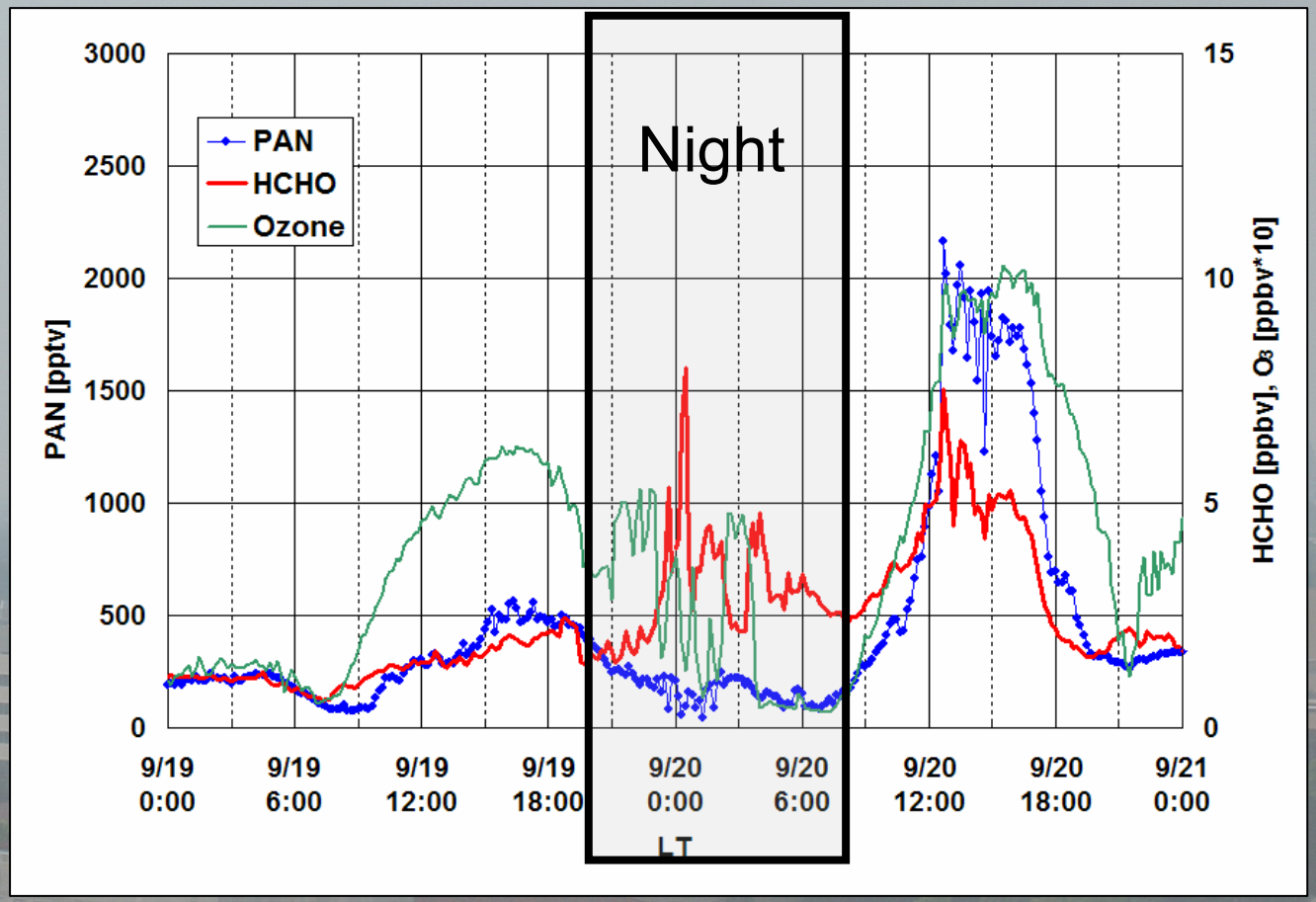
PI:
B. Rappenglueck
(UH)



Occasionally, events of elevated formaldehyde levels observed during nighttimes.

Formaldehyde, PAN, O_3

PI:
B. Rappenglueck
(UH)

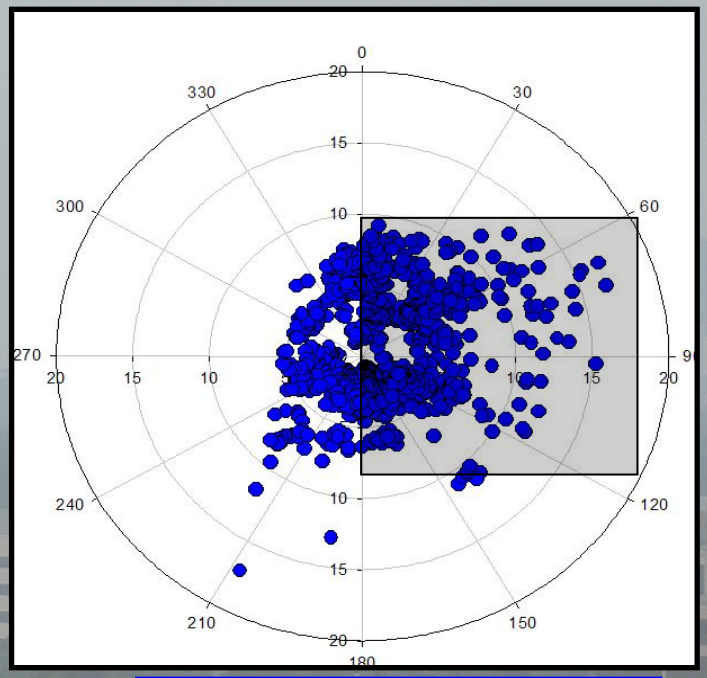


Indications for primary formaldehyde emissions? Indications for formaldehyde production through reaction of O_3 with alkenes? Indications for turbulent mixing?

Formaldehyde vs Wind Direction

PIs:
B. Rappenglueck
(UH)

09/15-09/30/06



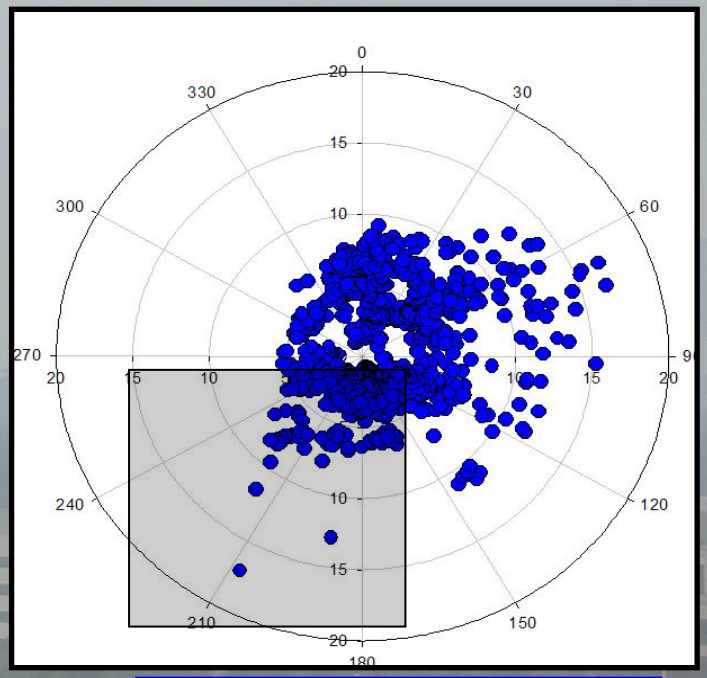
6:00 am – 8:00 pm (LT)

Daytime:
higher HCHO values associated with E directions (Ship Channel)

Formaldehyde vs Wind Direction

PIs:
B. Rappenglueck
(UH)

09/15-09/30/06



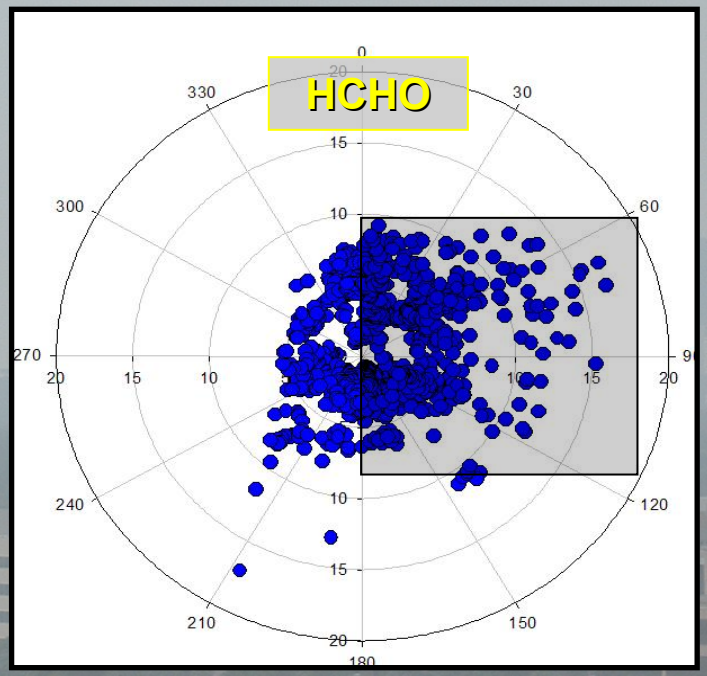
6:00 am – 8:00 pm (LT)

Daytime:
also some elevated values associated with SW winds (Parrish power plant?)

Formaldehyde vs Wind Direction

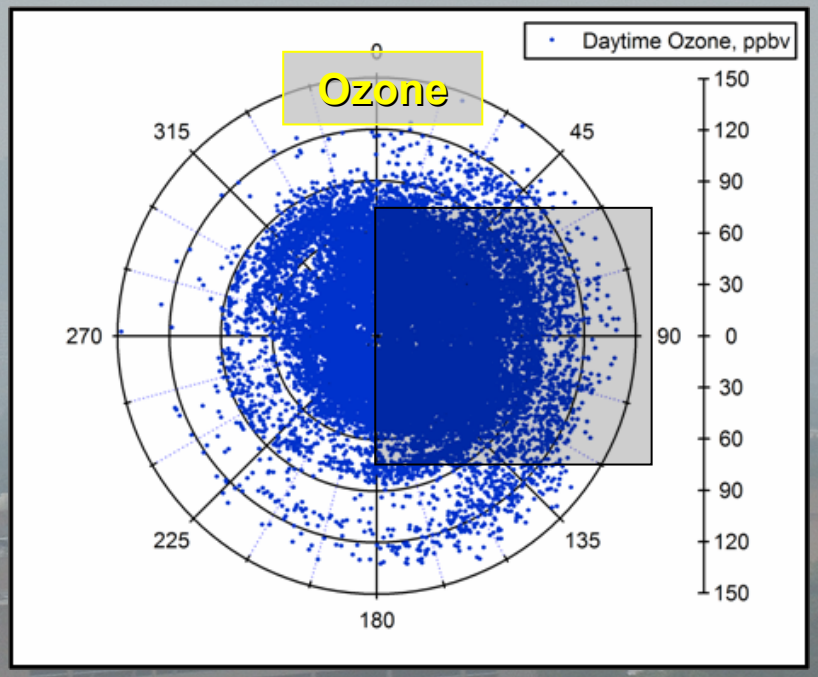
PIs:
B. Rappenglueck
(UH)

09/15-09/30/06



6:00 am – 8:00 pm (LT)

08/13-10/02/06



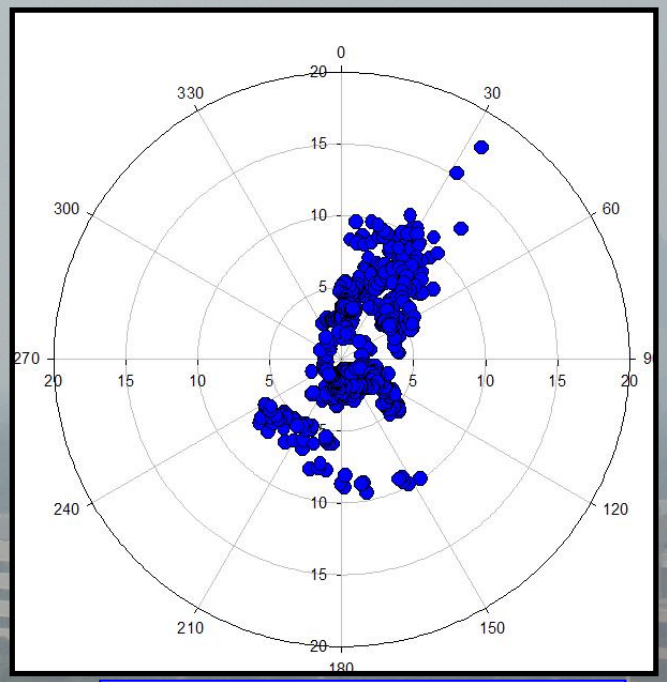
9:00 am – 9:00 pm (LT)

Daytime: Mostly secondary HCHO

Formaldehyde vs Wind Direction

PIs:
B. Rappenglueck
(UH)

09/15-09/30/06

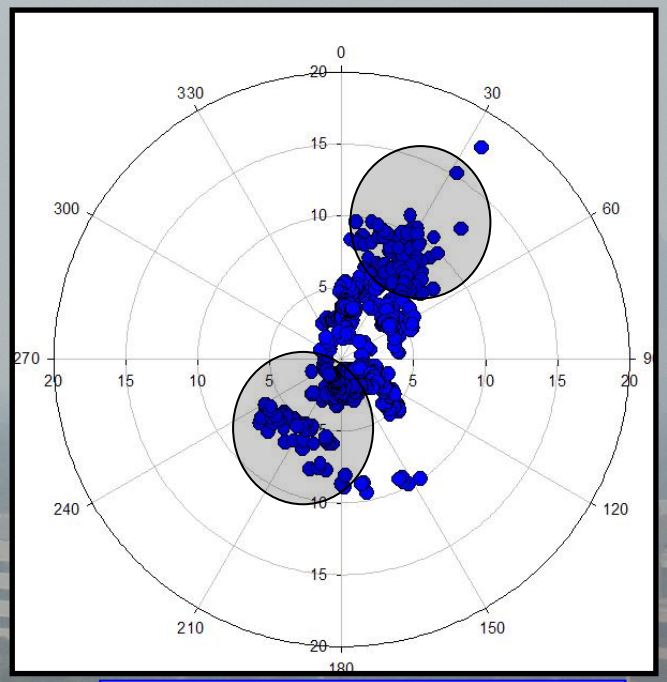


8:00 pm – 6:00 am (LT)

Formaldehyde vs Wind Direction

PIs:
B. Rappenglueck
(UH)

09/15-09/30/06



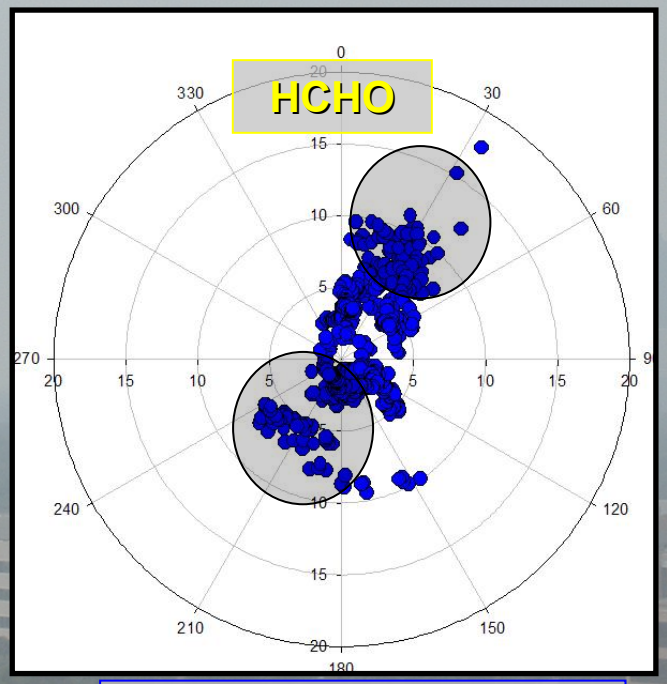
8:00 pm – 6:00 am (LT)

Nighttime: higher HCHO values associated with NE directions, sometimes SW winds.

Formaldehyde vs Wind Direction

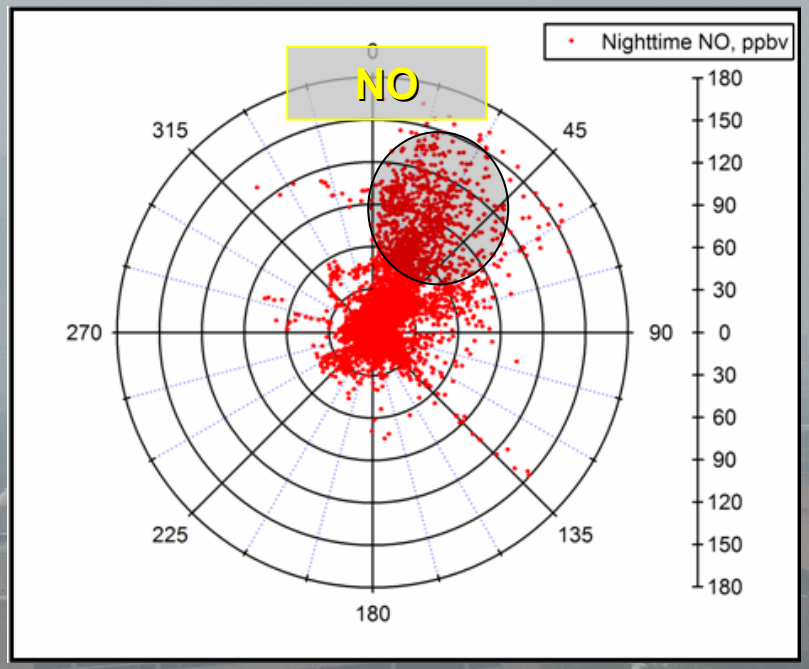
PIs:
B. Rappenglueck
(UH)

09/15-09/30/06



8:00 pm – 6:00 am (LT)

08/13-10/02/06



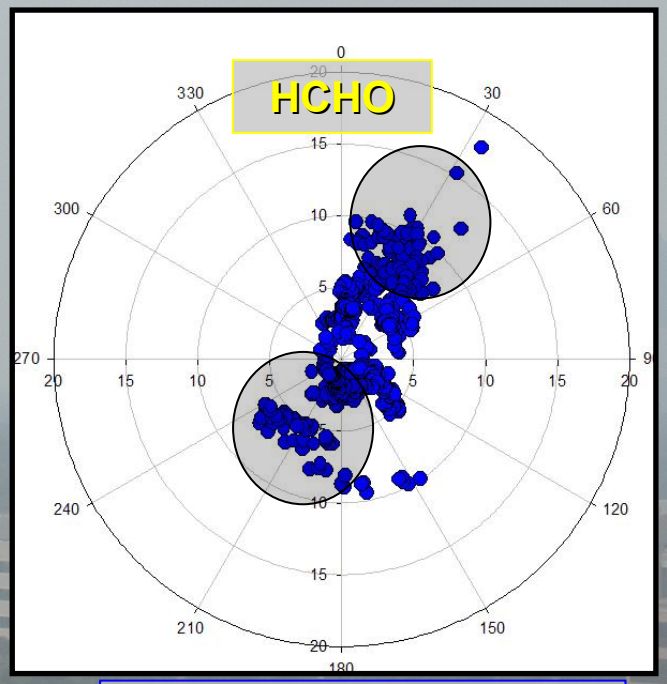
9:00 pm – 9:00 am (LT)

Nighttime: Secondary/primary (?) HCHO associated with NE-winds and SW winds ?

Formaldehyde vs Wind Direction

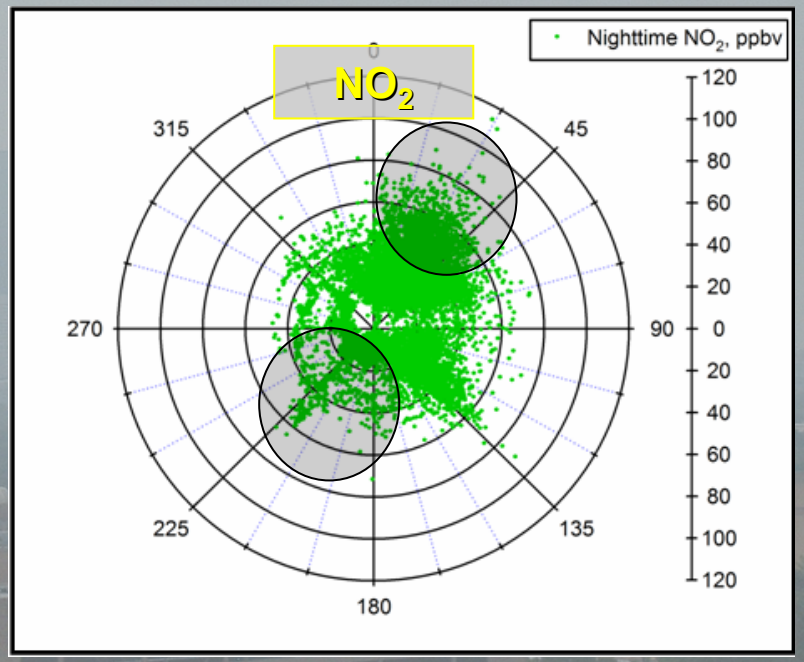
PIs:
B. Rappenglueck
(UH)

09/15-09/30/06



8:00 pm – 6:00 am (LT)

08/13-10/02/06

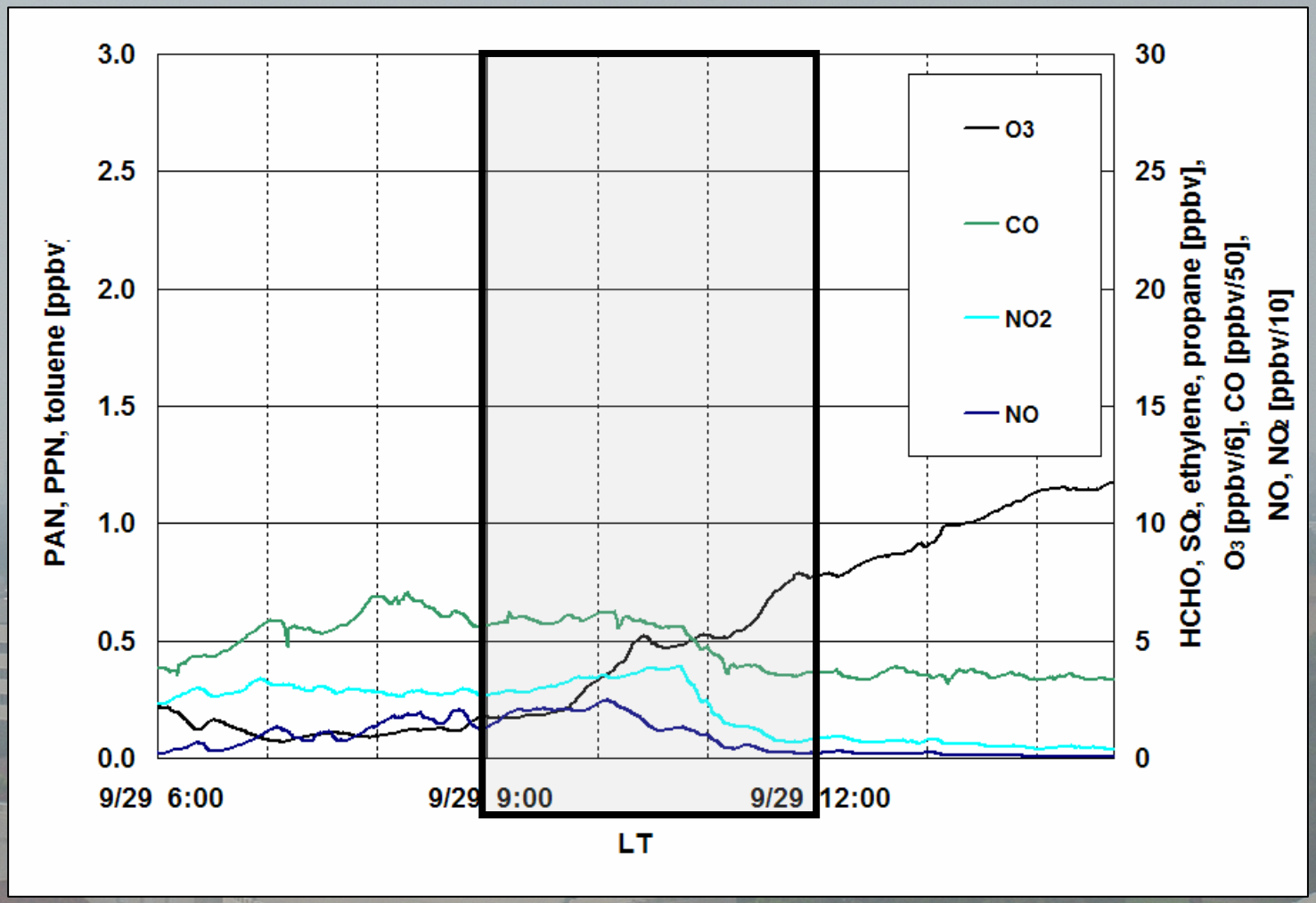


9:00 pm – 9:00 am (LT)

Nighttime: Secondary/primary (?) HCHO associated with NE-winds and SW winds ?

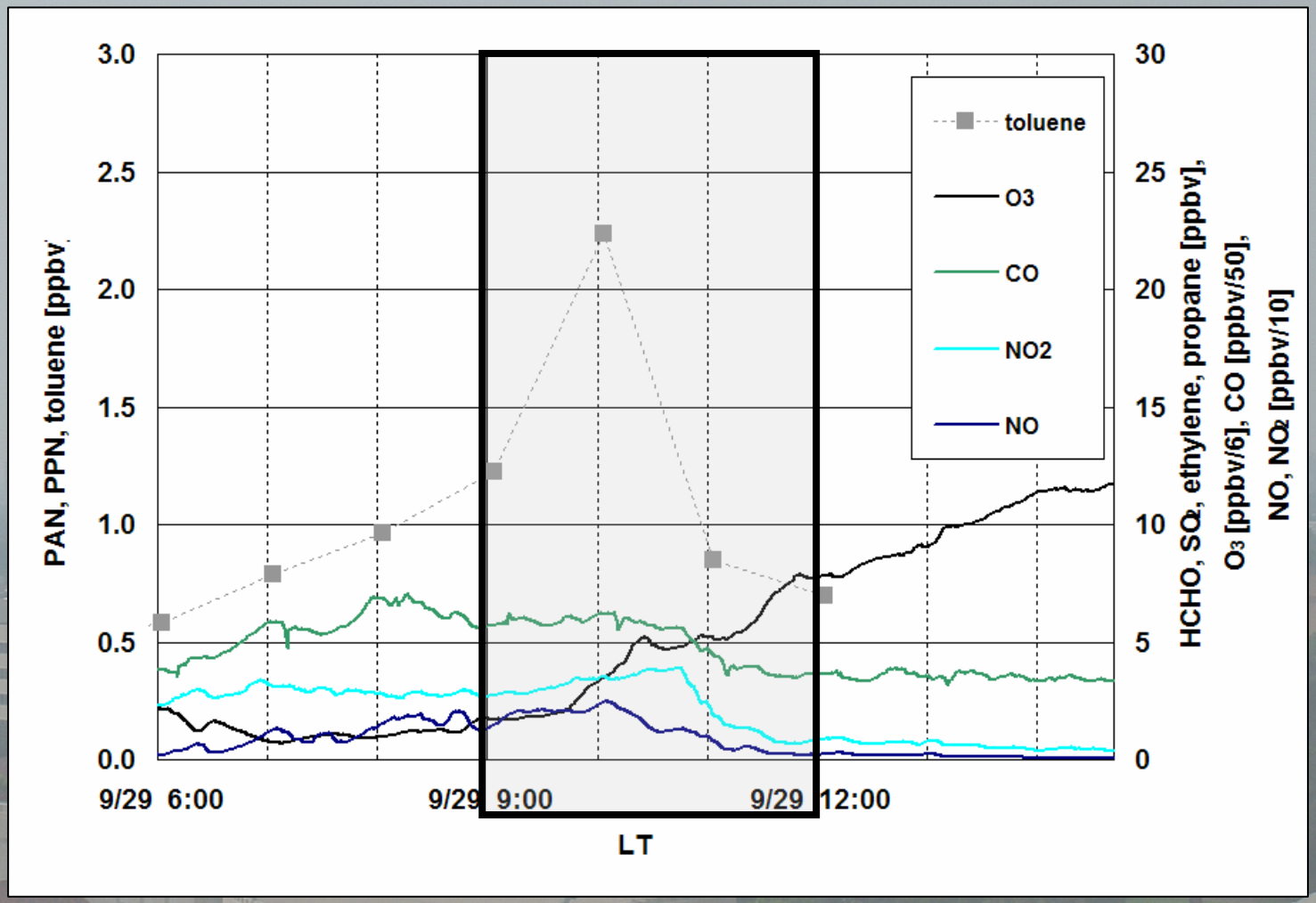
Event on September 29, 2006

PI:
B. Rappenglueck
(UH)



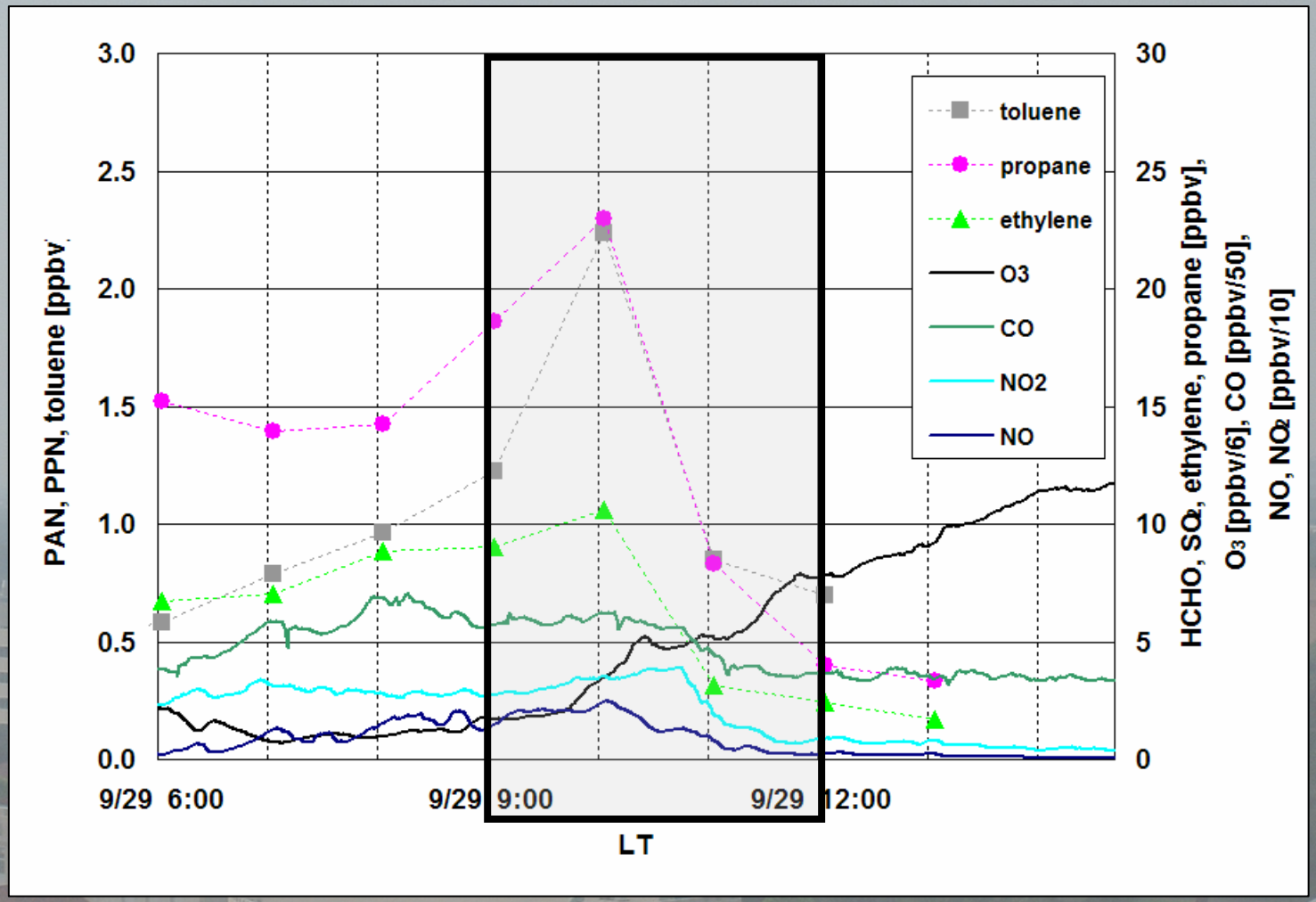
Event on September 29, 2006

PI:
B. Rappenglueck
(UH)



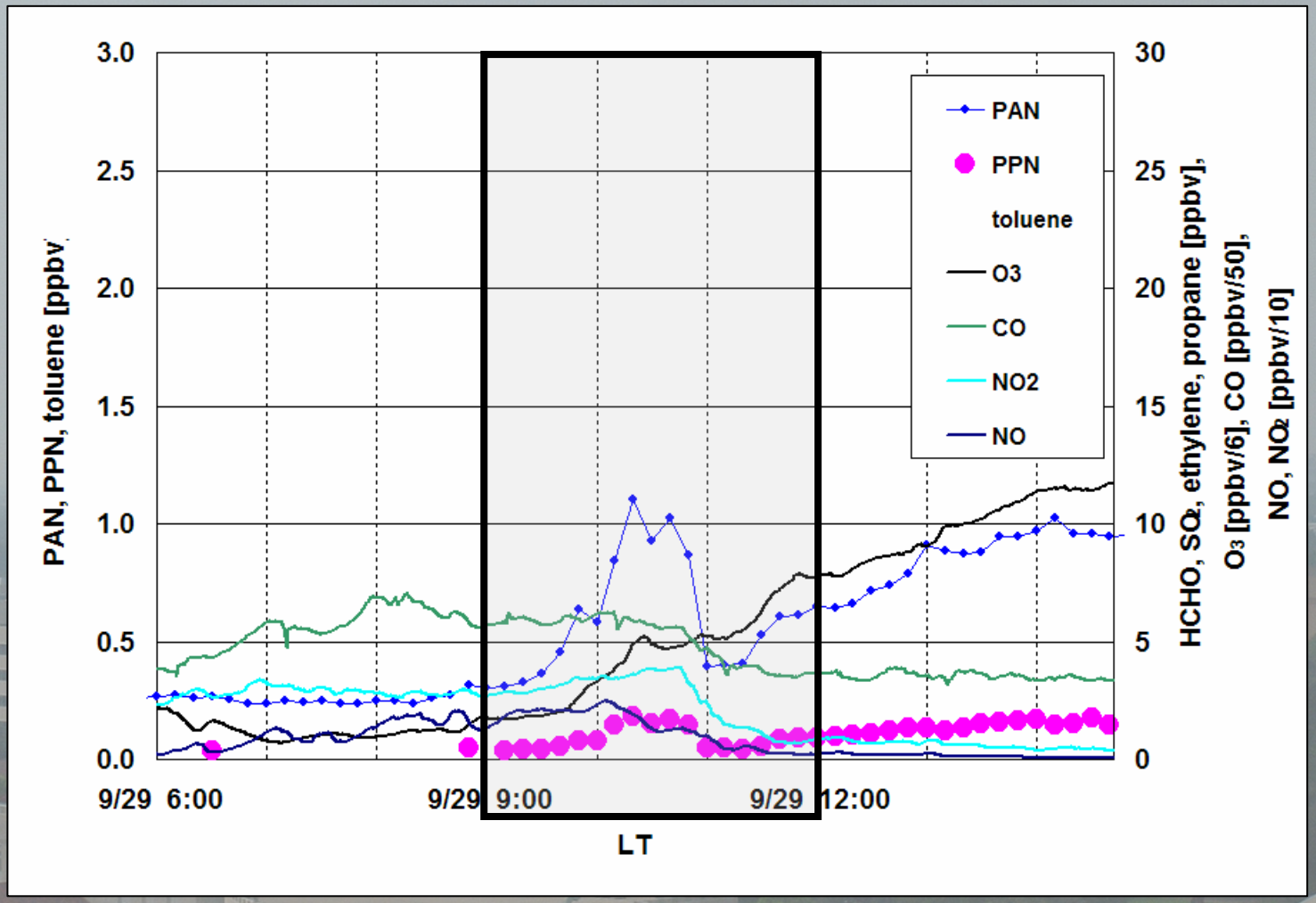
Event on September 29, 2006

PI:
B. Rappenglueck
(UH)



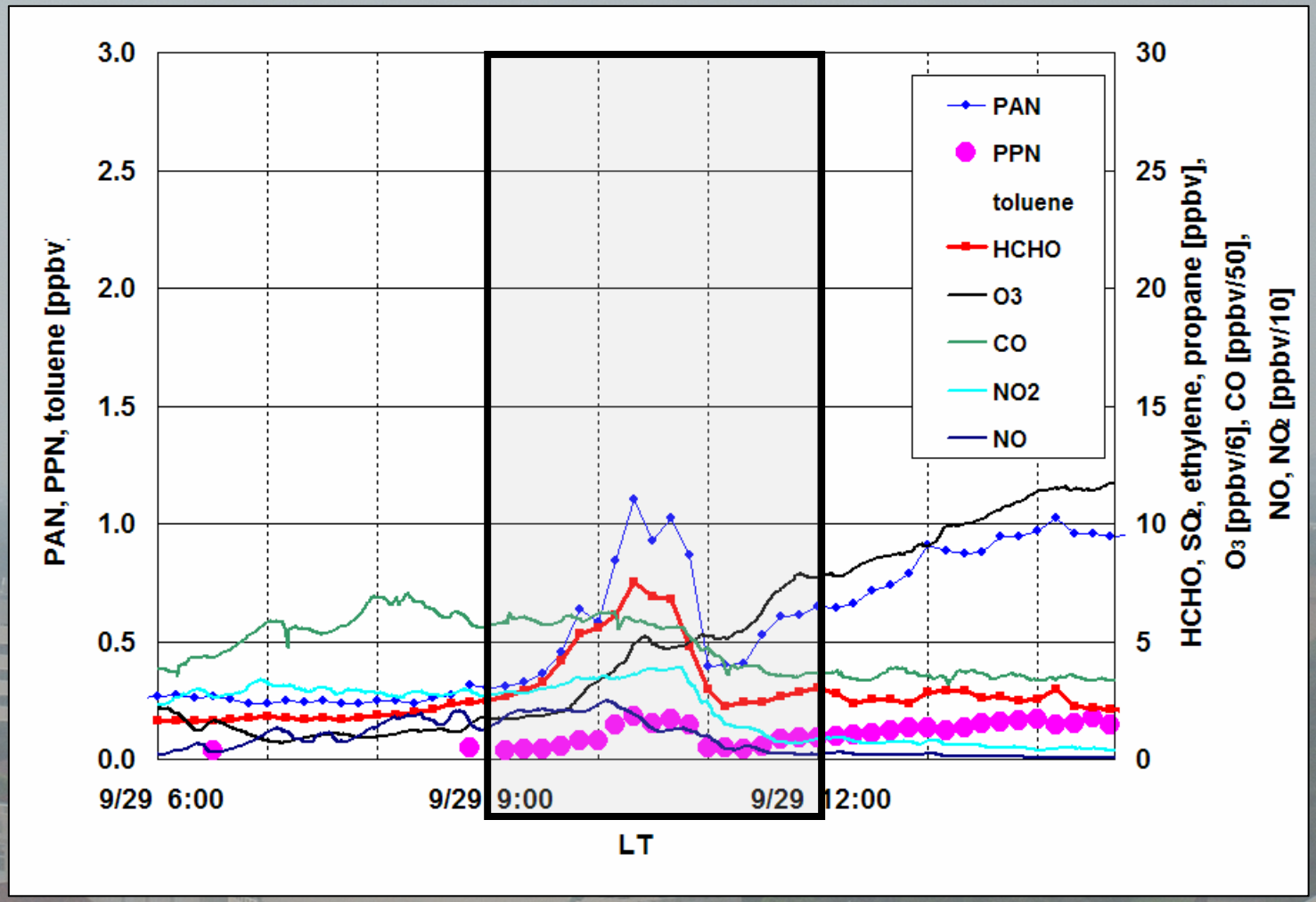
Event on September 29, 2006

PI:
B. Rappenglueck
(UH)



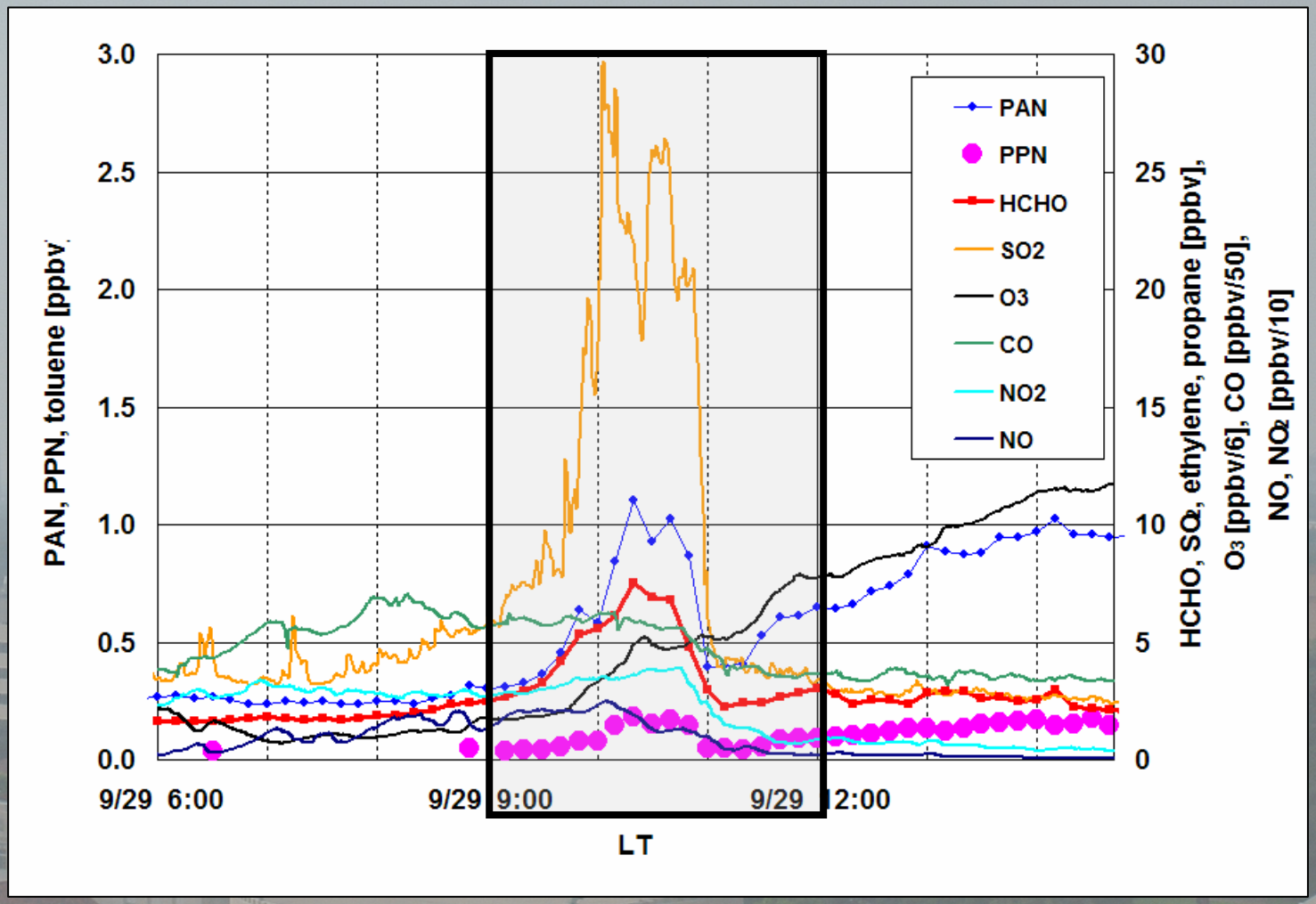
Event on September 29, 2006

PI:
B. Rappenglueck
(UH)



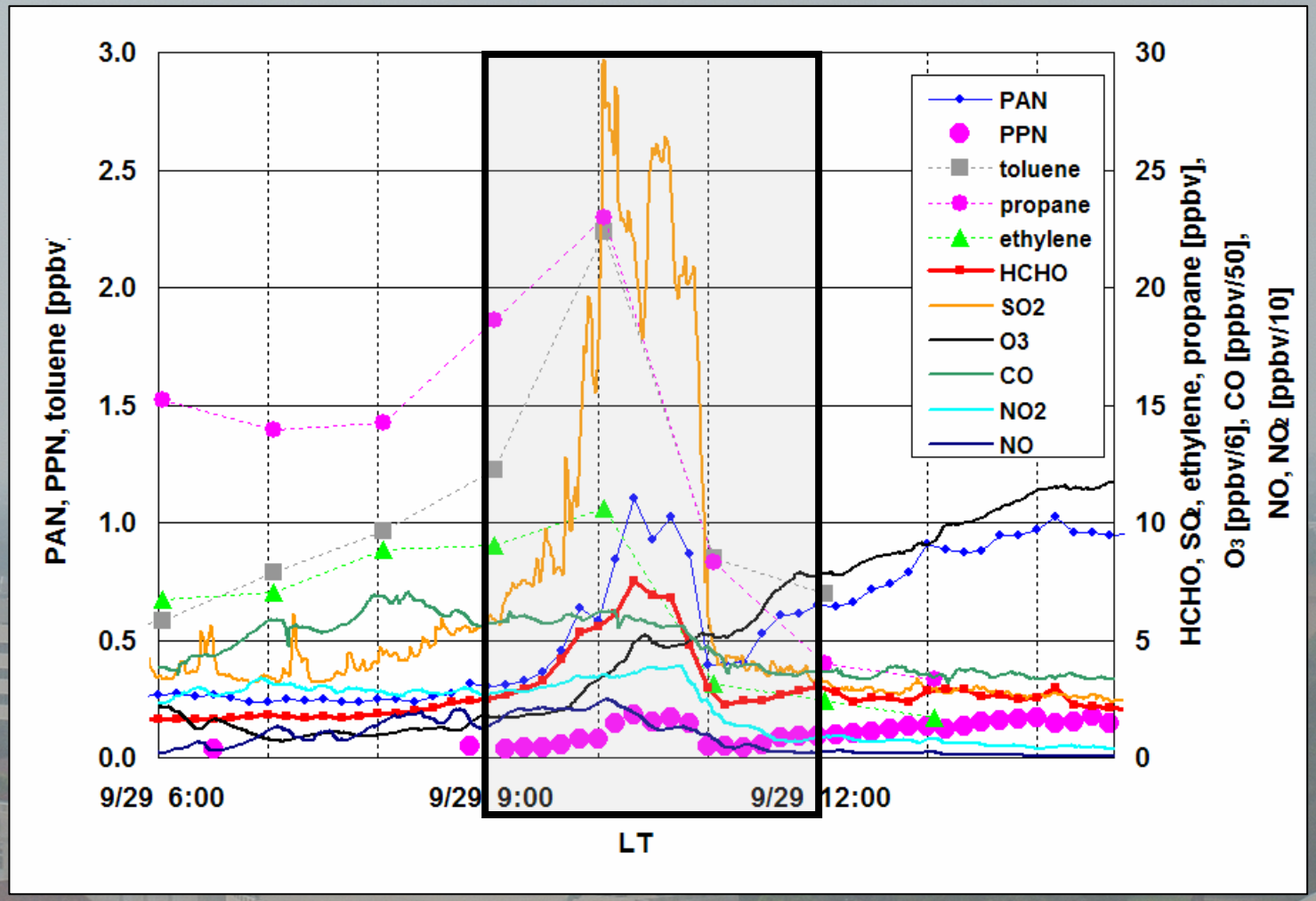
Event on September 29, 2006

PI:
B. Rappenglueck
(UH)



Event on September 29, 2006

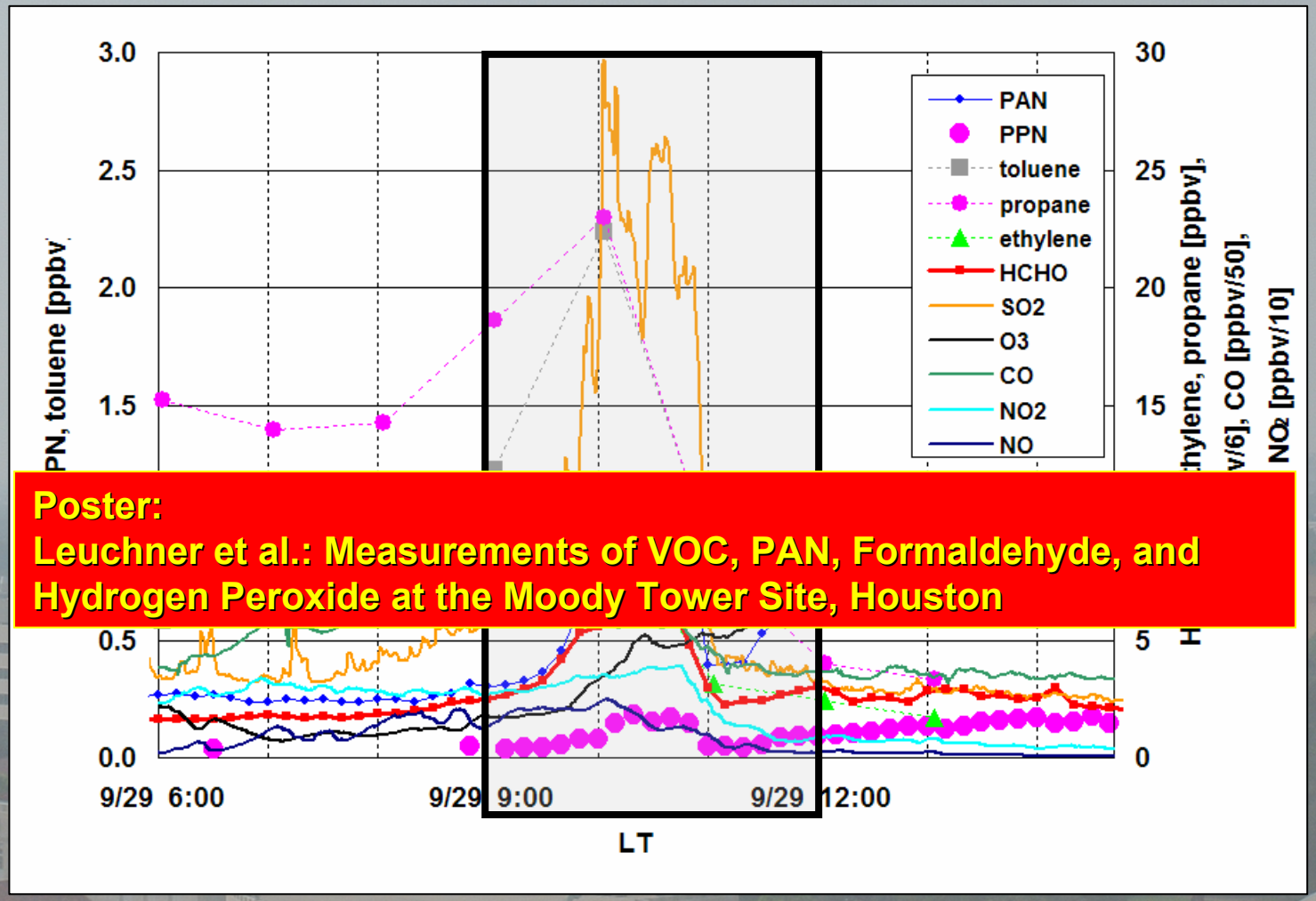
PI:
B. Rappenglueck
(UH)



Occasionally, elevated formaldehyde levels coincide with SO_2 and PANs (less correlated with CO, NO_x, O_3)

Event on September 29, 2006

PI:
B. Rappenglueck
(UH)

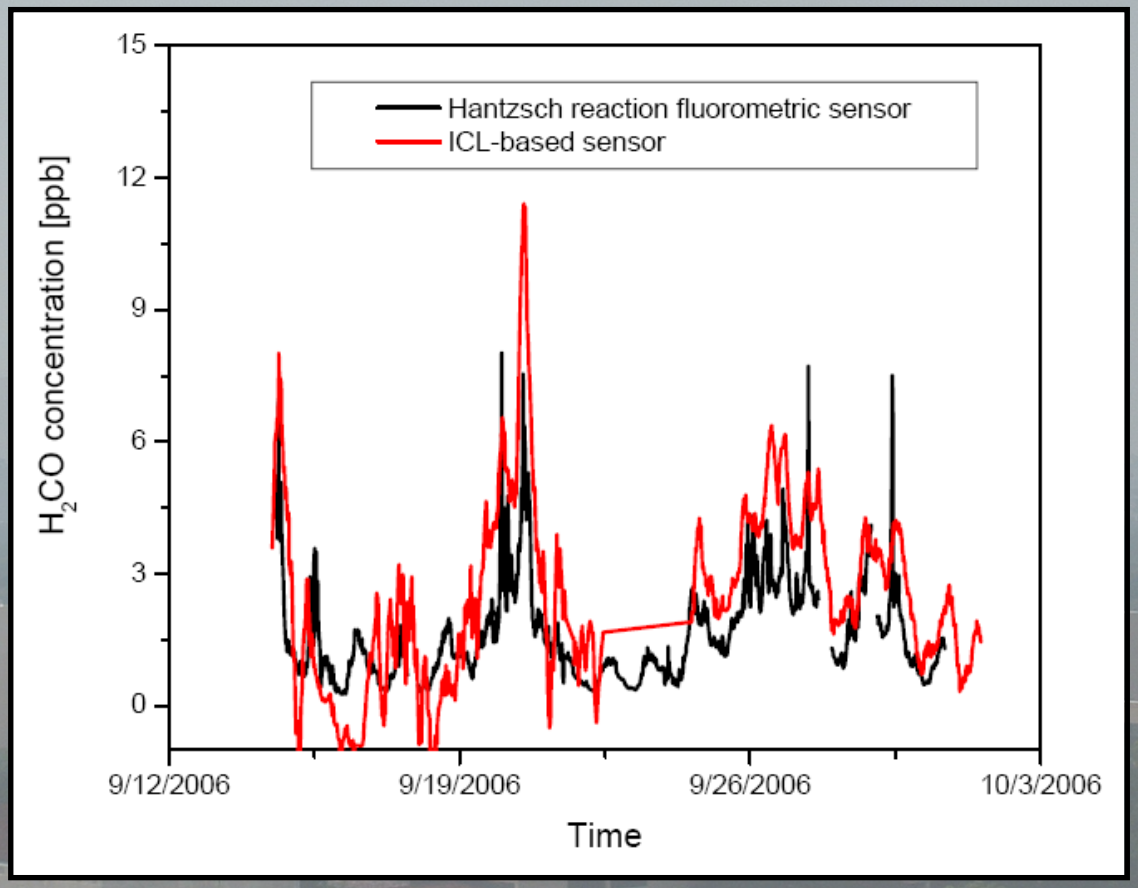


Poster:
Leuchner et al.: Measurements of VOC, PAN, Formaldehyde, and Hydrogen Peroxide at the Moody Tower Site, Houston

Occasionally, elevated formaldehyde levels coincide with SO_2 and PANs (less correlated with CO, NO_x, O_3)

Formaldehyde comparison (in-situ)

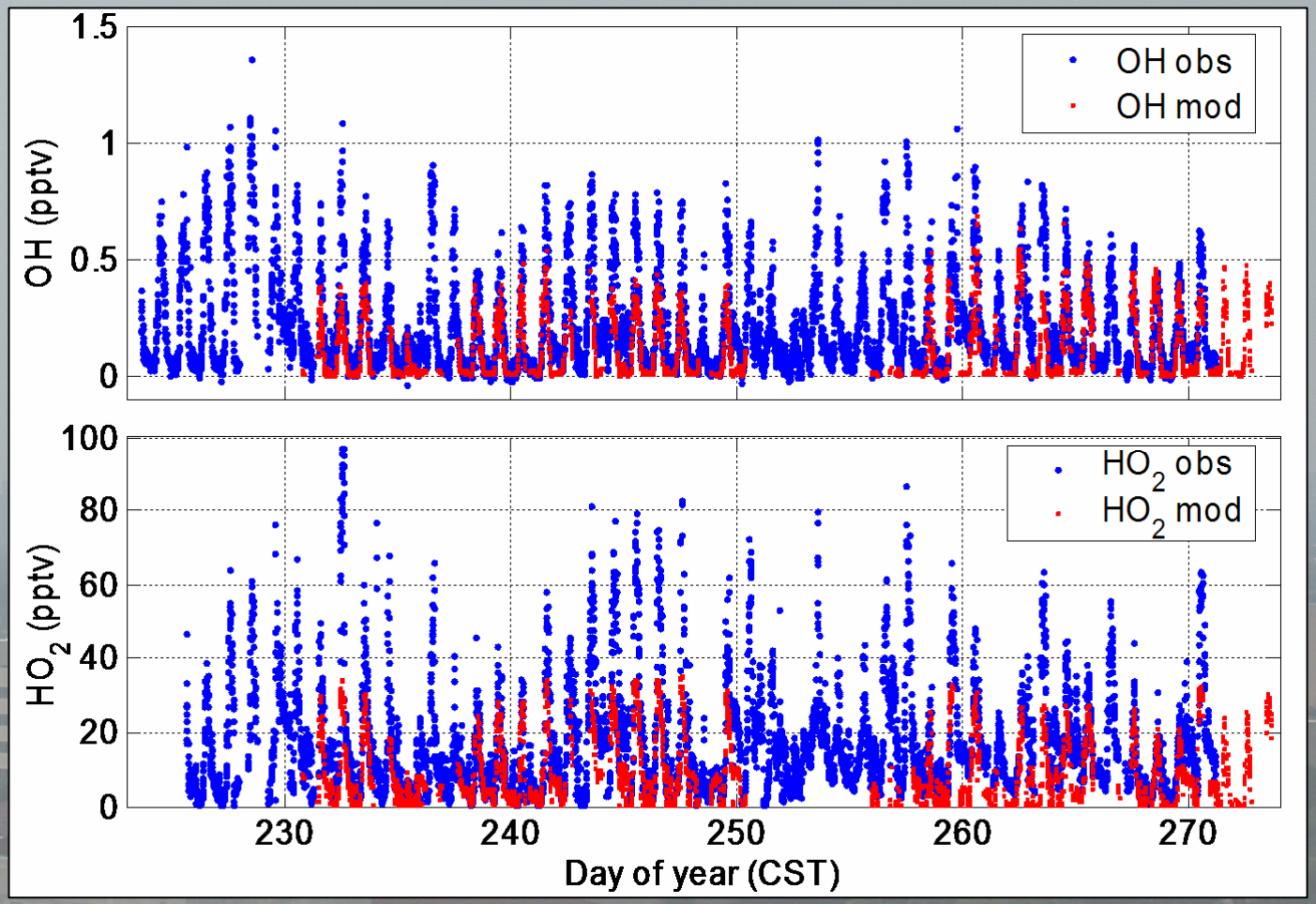
PI:
M. Fraser/B. Rappenglueck
(Rice/UH)



Comparison between interband cascade (IC) laser system (absorption at 3.5 µm) [Rice] and the Hantzsch-based instrumentation [UH].

OH, HO_2

PI:
B. Brune
(Penn State)

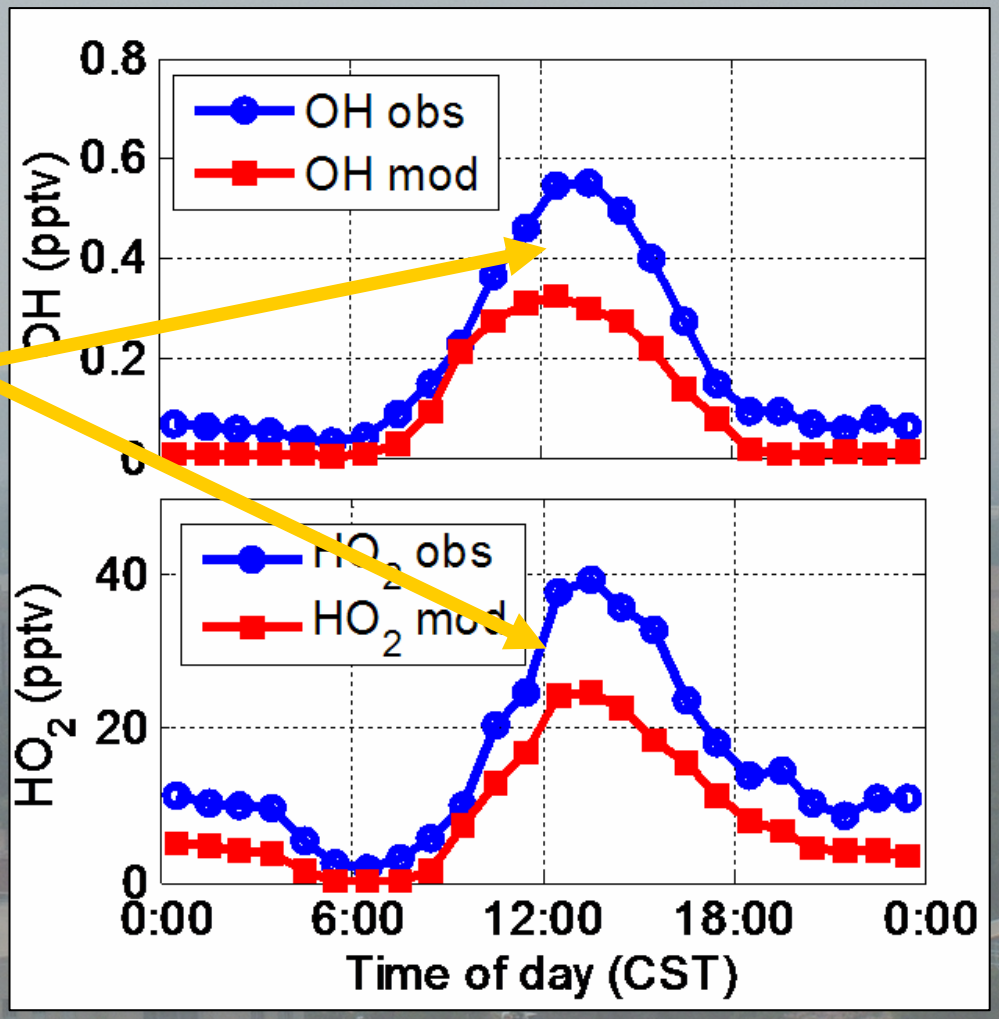


Typical diurnal variations of OH and HO_2 were observed.
OH: mid-day peak mixing ratios varied from 0.5 to 1.0 pptv.
HO_2: mid-day peak mixing ratios varied from 40 to 100 pptv.

OH, HO_2

PI:
B. Brune
(Penn State)

On average, both OH and HO_2 are under-predicted, day and night, which may indicate missing OH sources and/or incomplete chemistry in the model.



HO_x Budget

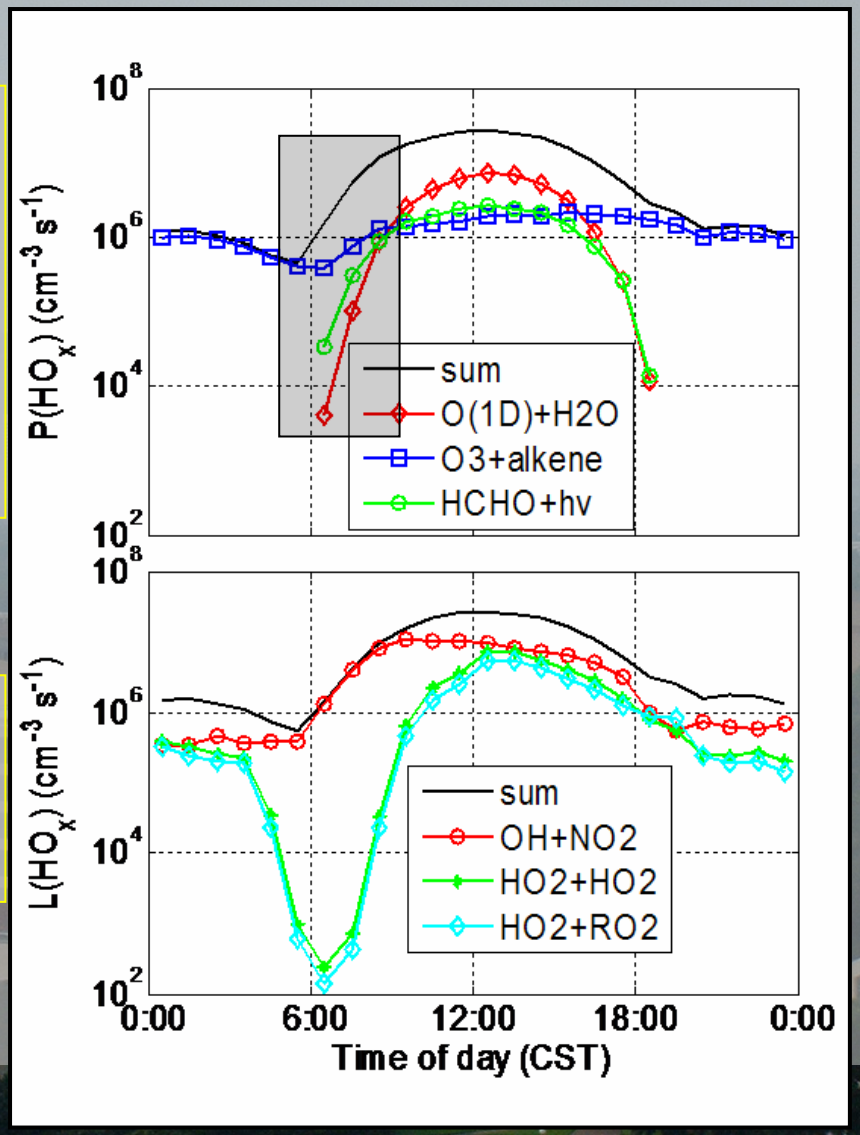
PI:
B. Brune
(Penn State)

P(HO_x):
dominant:
$O(^1D) + H_2O$ during daytime
O_3+ alkene reactions at night

others:
photolysis of HONO, HNO_3, peroxides, and glyoxal

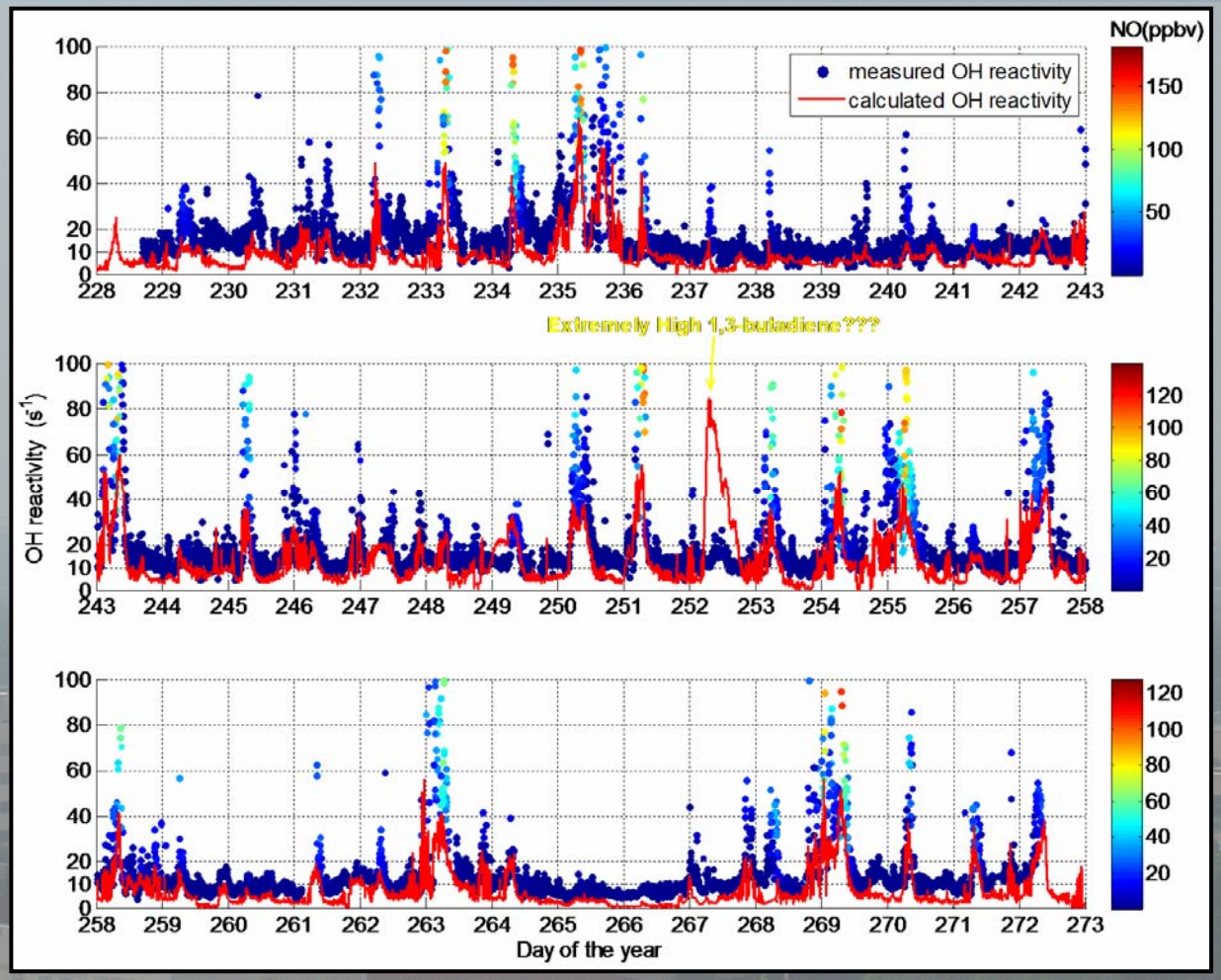
L(HO_x):
dominant: $OH+NO_2$

others: HO_2+HO_2, and HO_2+RO_2



OH-Reactivity

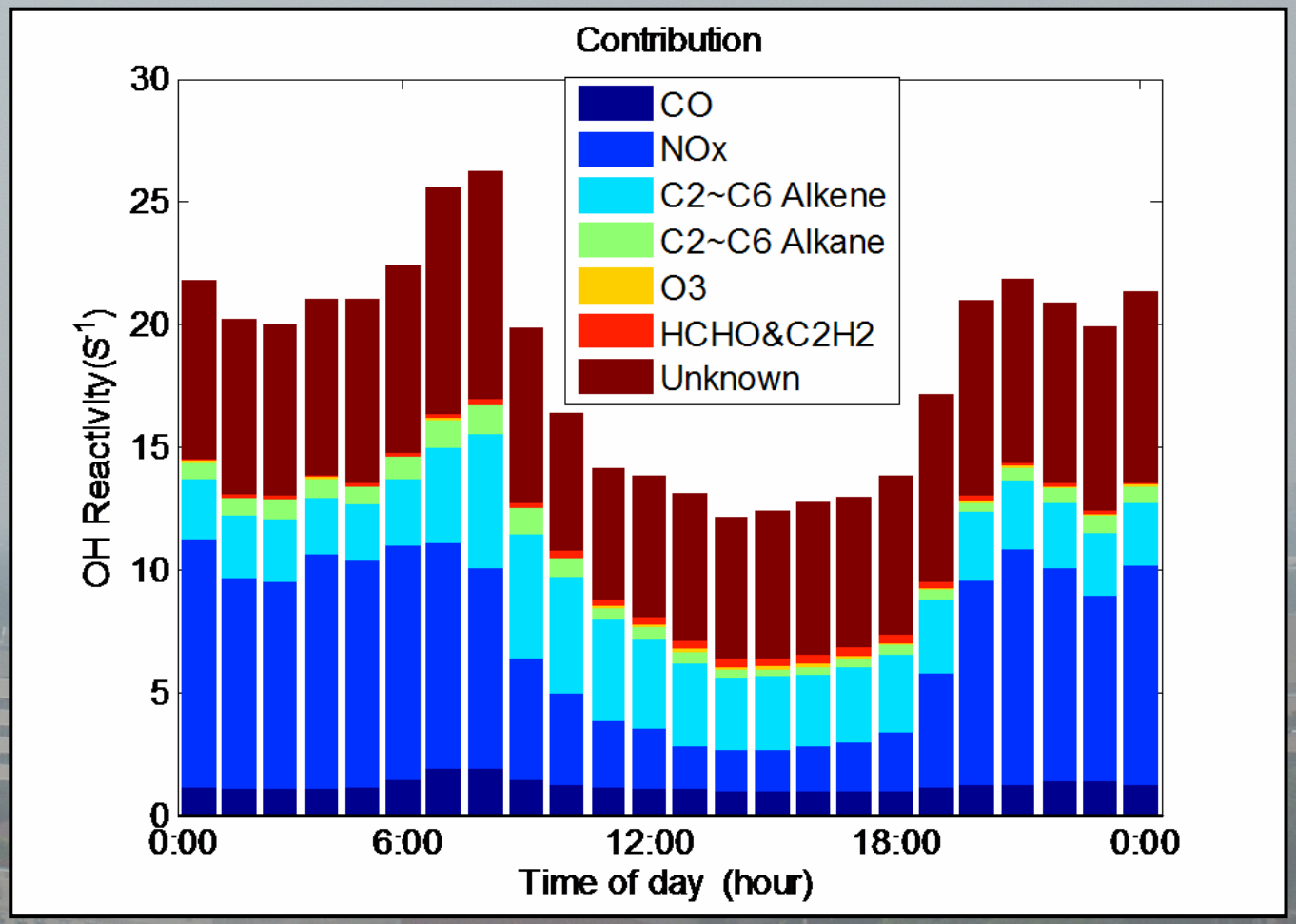
PI:
B. Brune
(Penn State)



Calculated OH reactivity tends to be lower than the observed OH reactivity, because the calculations are only based on limited data: (1) NO_x,CO,O_3, (2) C_2-C_6 alkenes, (3) C_2-C_6 alkanes, (4) HCHO, (5) Acetylene

OH-Reactivity

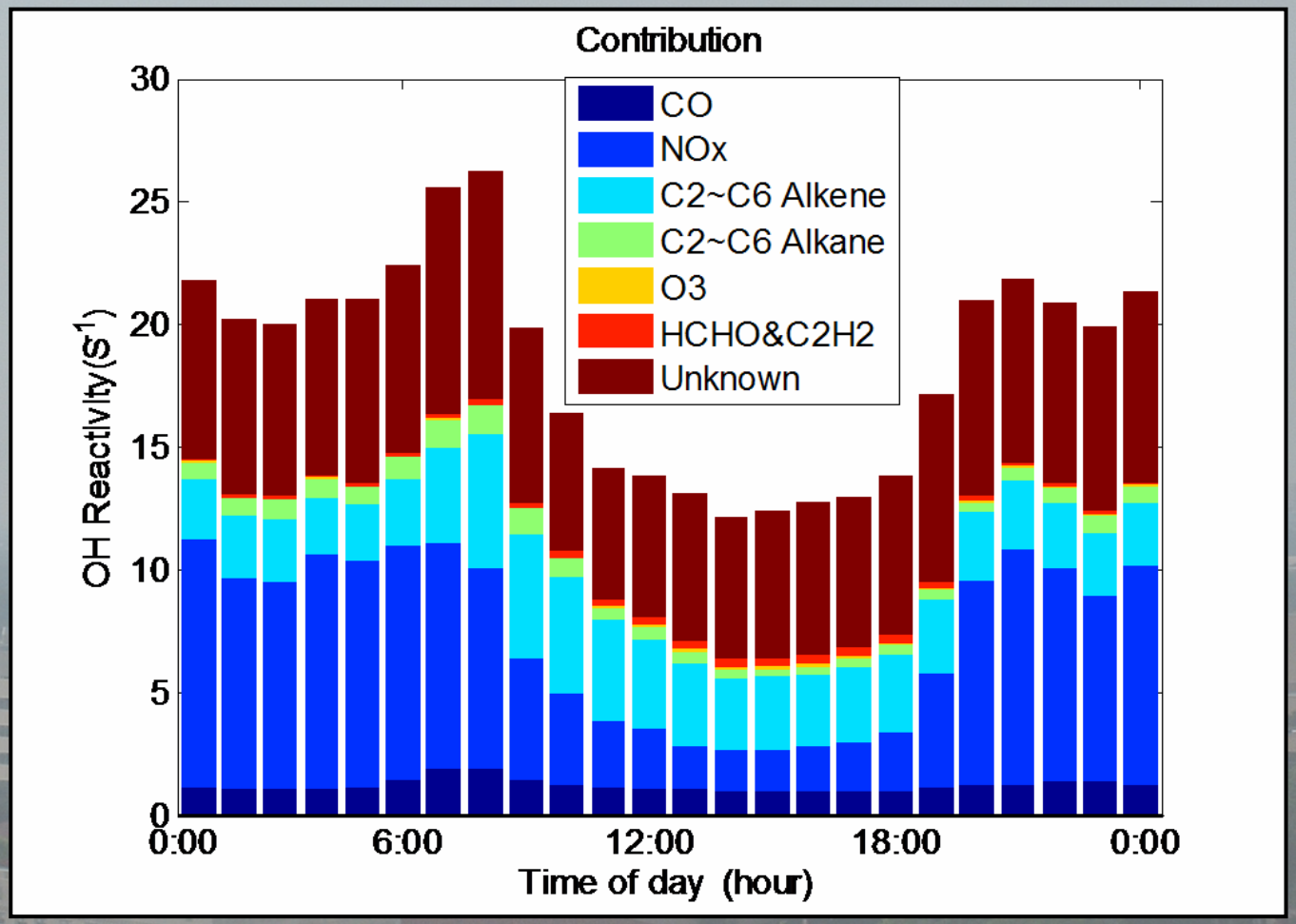
PI:
B. Brune
(Penn State)



NO_x is an important contributor to OH loss.
Unknown OH reactivity is about 7-8 s^{-1} all day along.

OH-Reactivity

PI:
B. Brune
(Penn State)



The unknown is the difference between the measurements and calculations using currently available data.
Aromatics and large carbonyls are not included in the calculations yet and should be in the unknown.

OH-Reactivity

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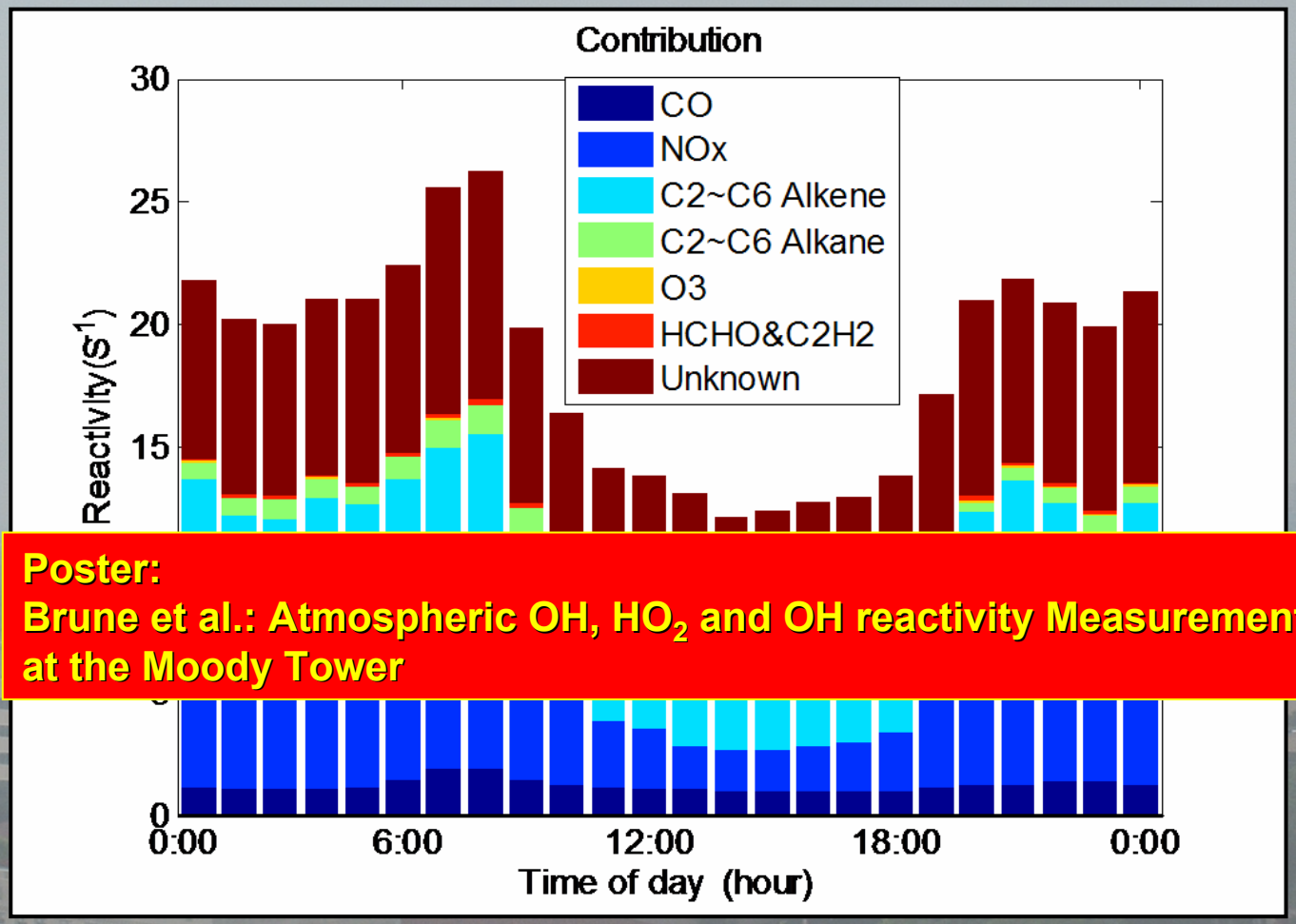
(Penn State)



Poster:
Brune et al.: Atmospheric OH, HO_2 and OH reactivity Measurements at the Moody Tower

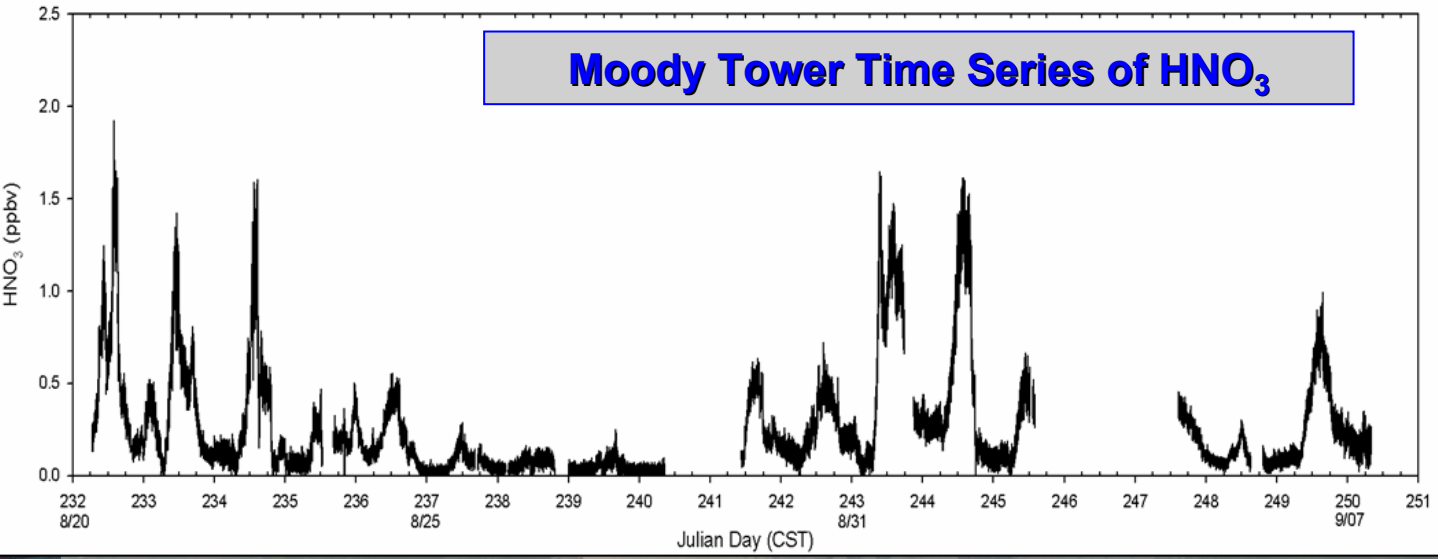
The unknown is the difference between the measurements and calculations using currently available data.
Aromatics and large carbonyls are not included in the calculations yet and should be in the unknown.

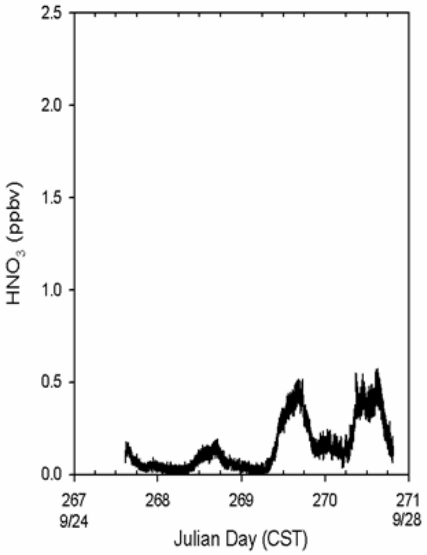
HNO_3

PI:
R. Zhang
(Texas A&M)

HNO_3 with ID-CIMS.

Measurement periods:
08/20-09/07
09/24-09/27





HNO_3

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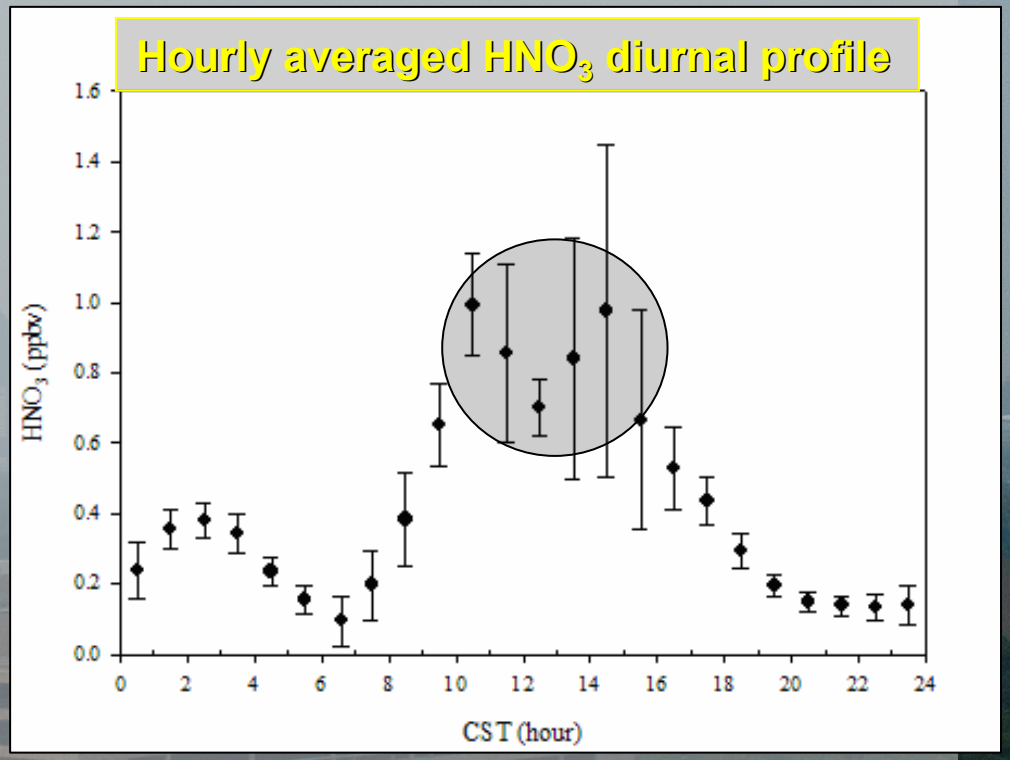


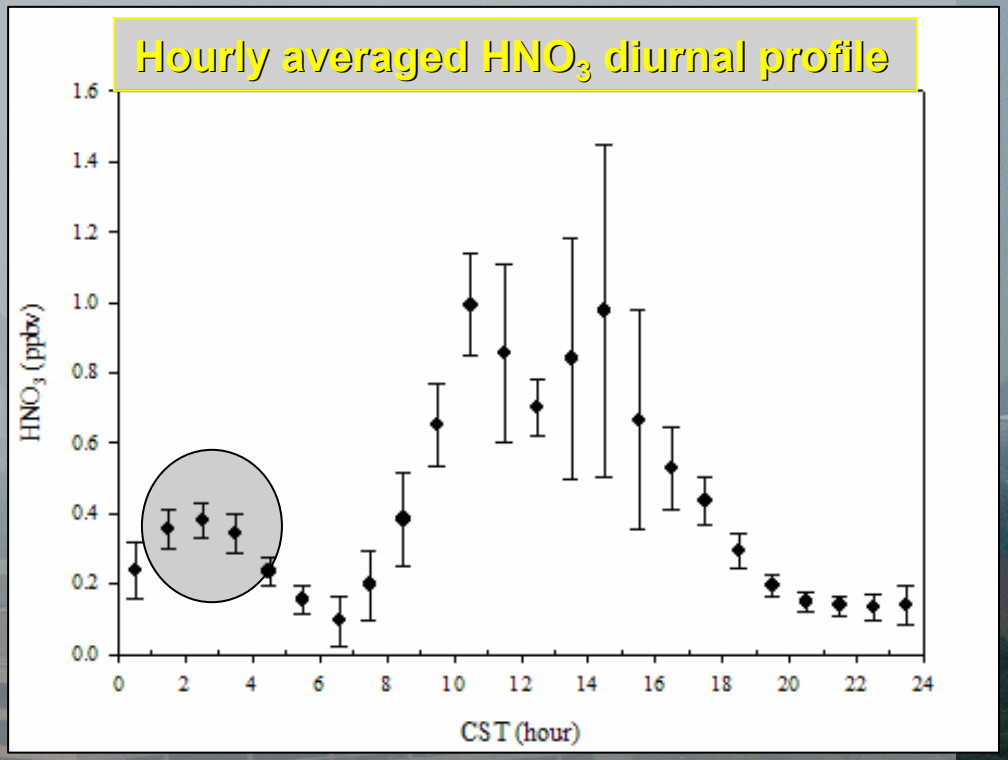
Daytime HNO_3 followed the solar cycle and was consistent with its role in the photochemical processes. The peak value was less than 1.5 ppbv, which implied that the O_3 production might be NO_x limited.

HNO_3

PI:
R. Zhang
(Texas A&M)

HNO_3 with ID-CIMS.

Measurement periods:
08/20-09/07
09/24-09/27



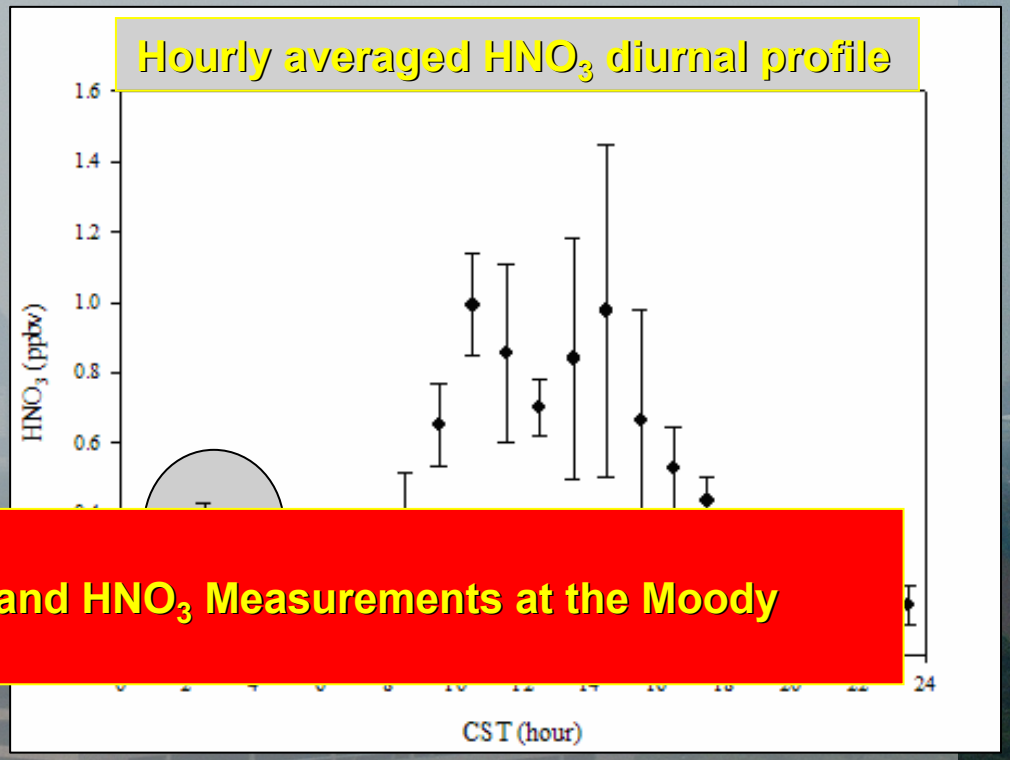
Small peak at 2:30 AM, when no photochemistry could occur.
Two possible explanations:
(i) HNO_3 formed locally through heterogeneous reactions and
(ii) returning of aged air masses from the ocean.

HNO_3

PI:
R. Zhang
(Texas A&M)

HNO_3 with ID-CIMS.

Measurement periods:
08/20-09/07
09/24-09/27

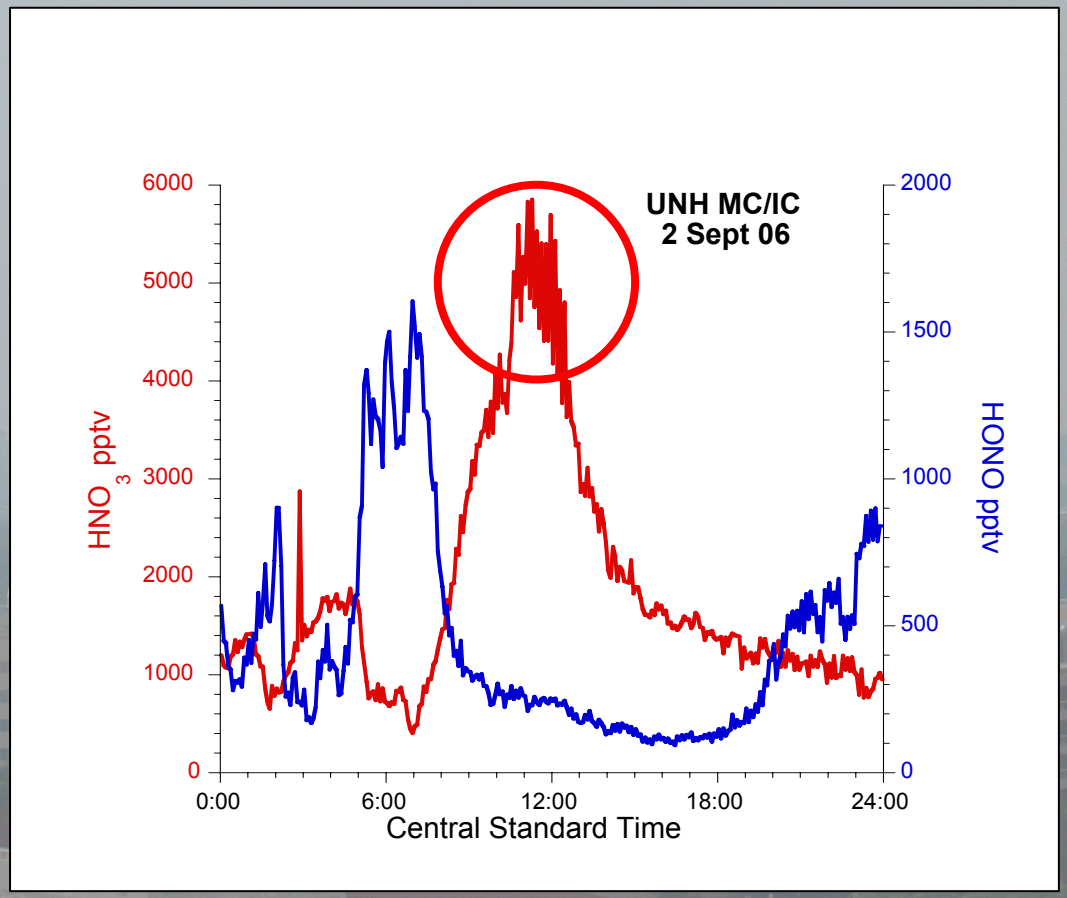


Poster:
Zheng and Zhang: VOCs and HNO_3 Measurements at the Moody Tower

Small peak at 2:30 AM, when no photochemistry could occur.
Two possible explanations:
(i) HNO_3 formed locally through heterogeneous reactions and
(ii) returning of aged air masses from the ocean.

HNO_3, HONO

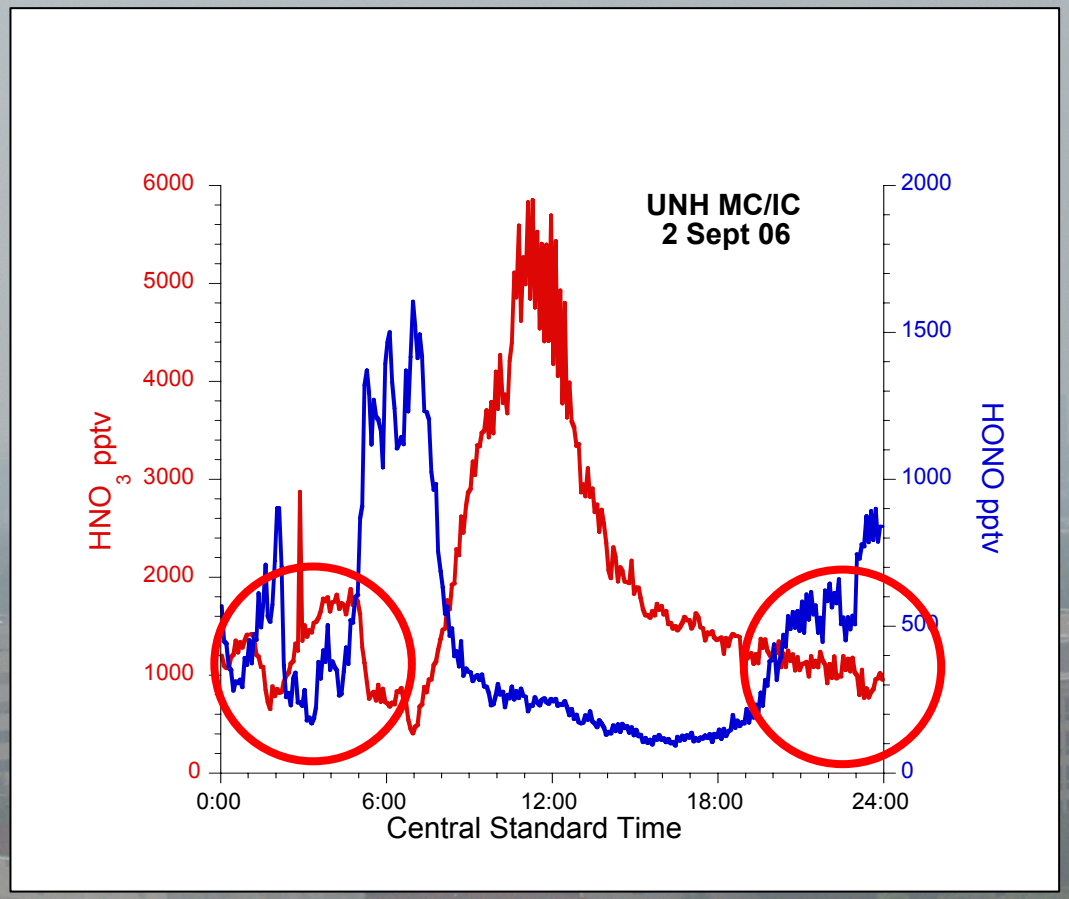
PI:
J. Dibb
(U New Hampshire)



HNO_3 mixing ratio closely follows O_3 trend.

HNO_3, HONO

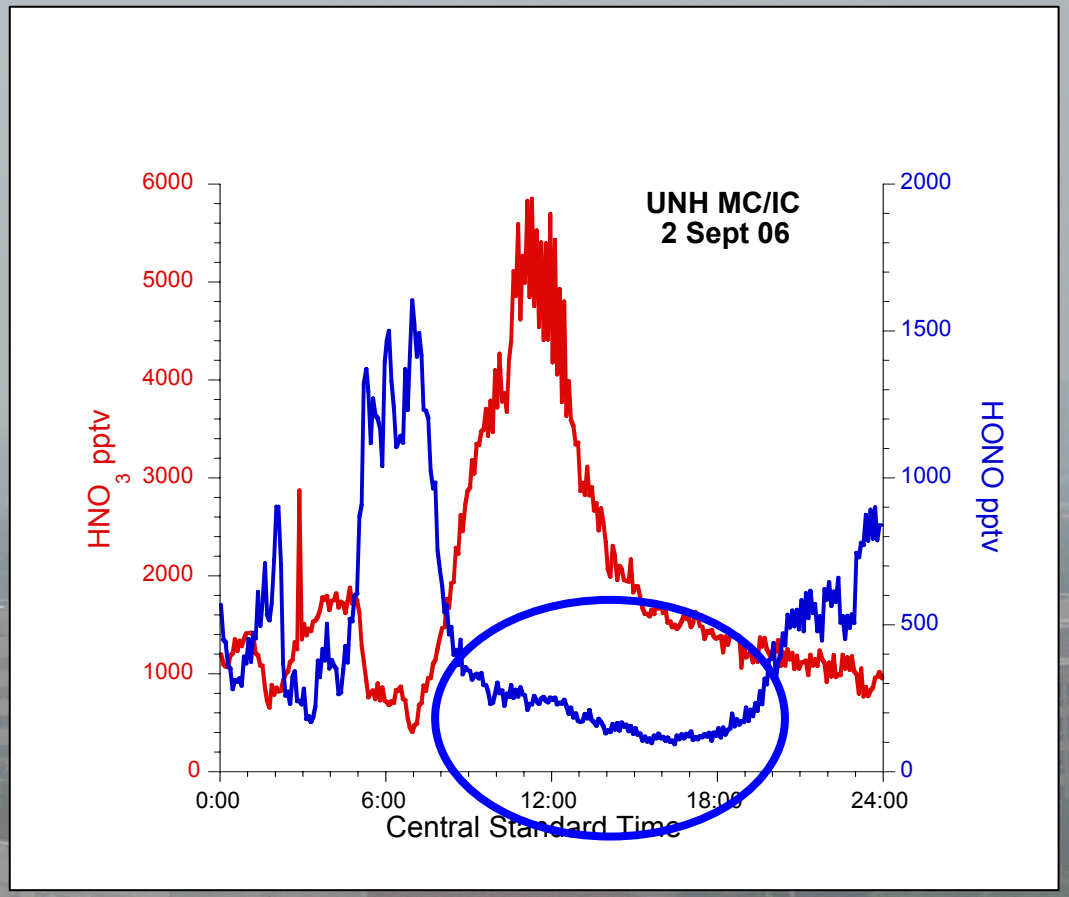
PI:
J. Dibb
(U New Hampshire)



HNO_3 lower at night, but still appreciable, suggesting significant production via NO_3 and N_2O_5.

HNO_3, HONO

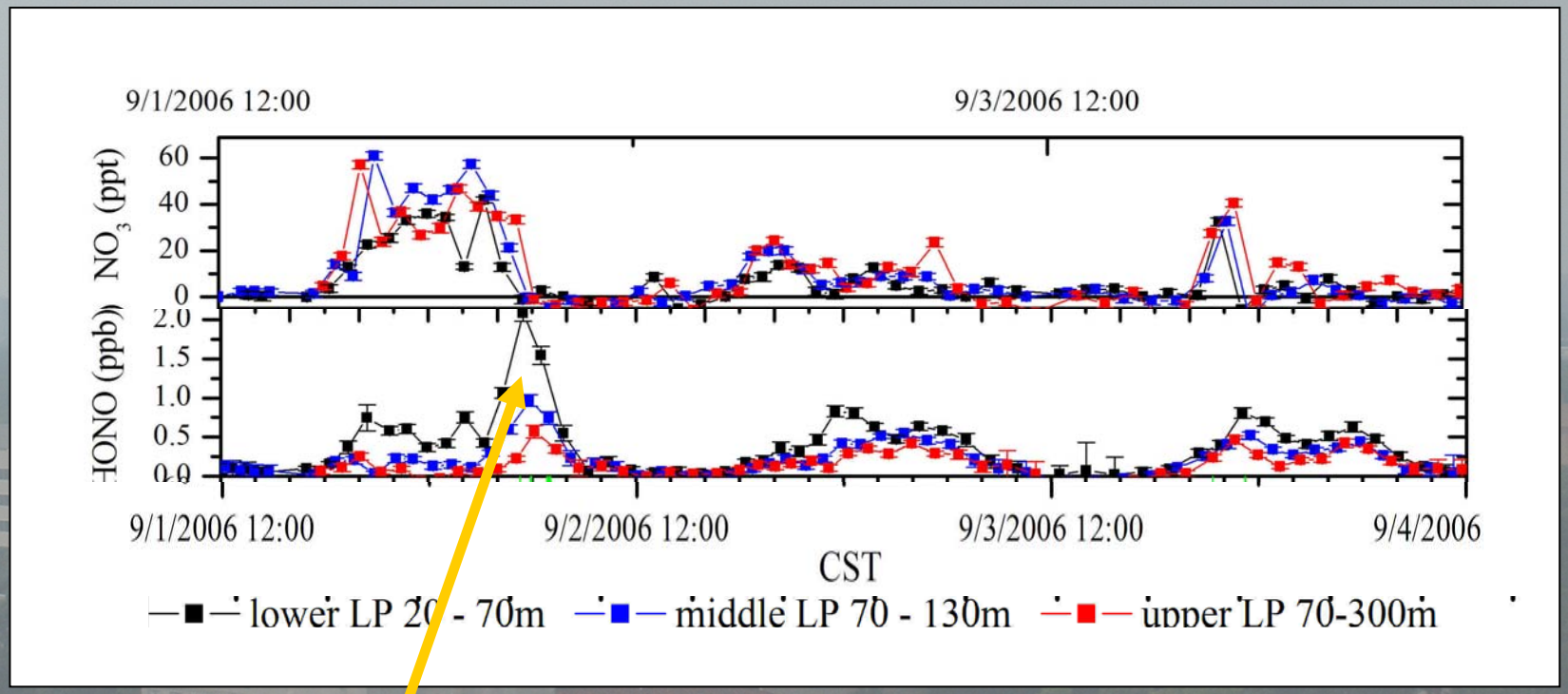
PI:
J. Dibb
(U New Hampshire)



HONO mixing ratios of several hundred ppt throughout the day!

DOAS: HONO, NO_3

PI: Stutz (UCLA)

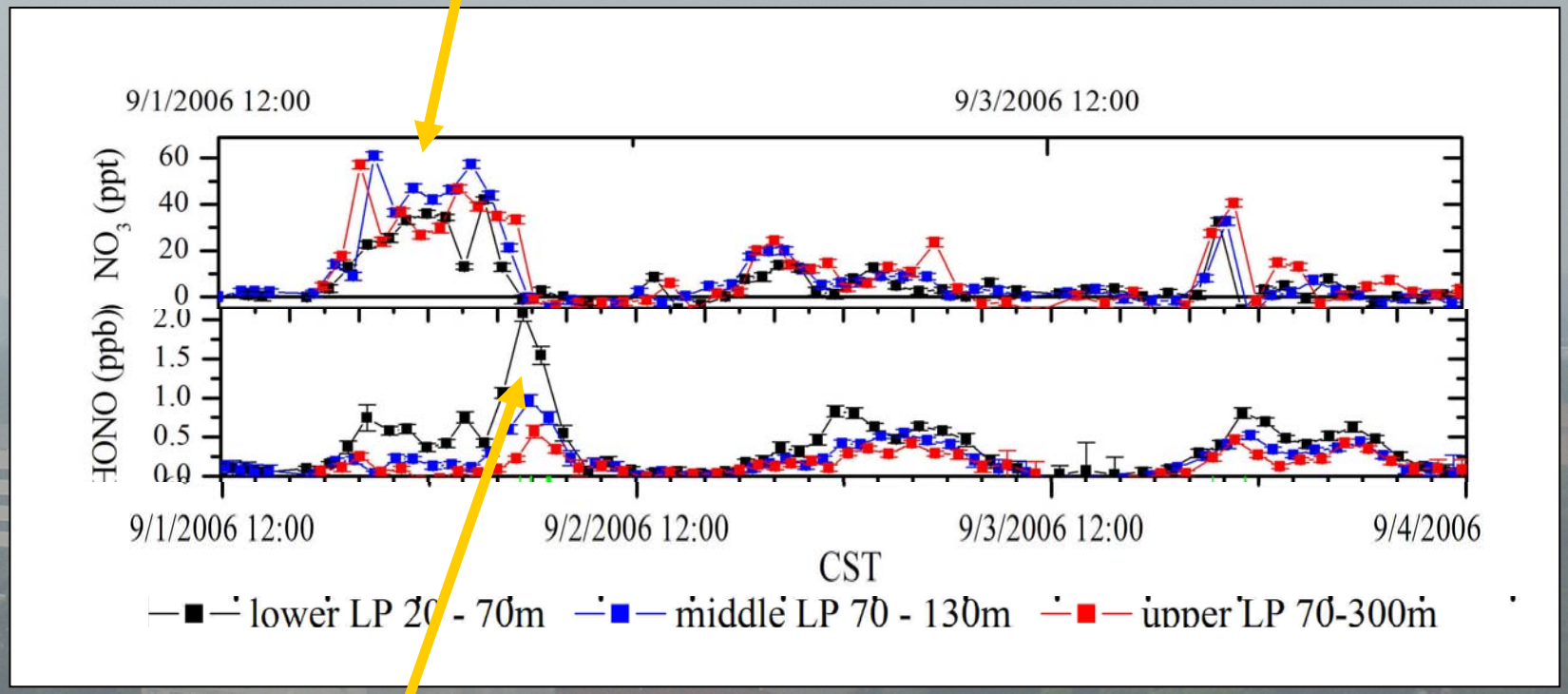


HONO shows higher values near the ground, reaching mixing ratios of up to 2 ppb.

DOAS: HONO, NO_3

PI: Stutz (UCLA)

NO_3 mixing ratios of up to 60 ppt during some nights. Vertical gradients less pronounced than expected.

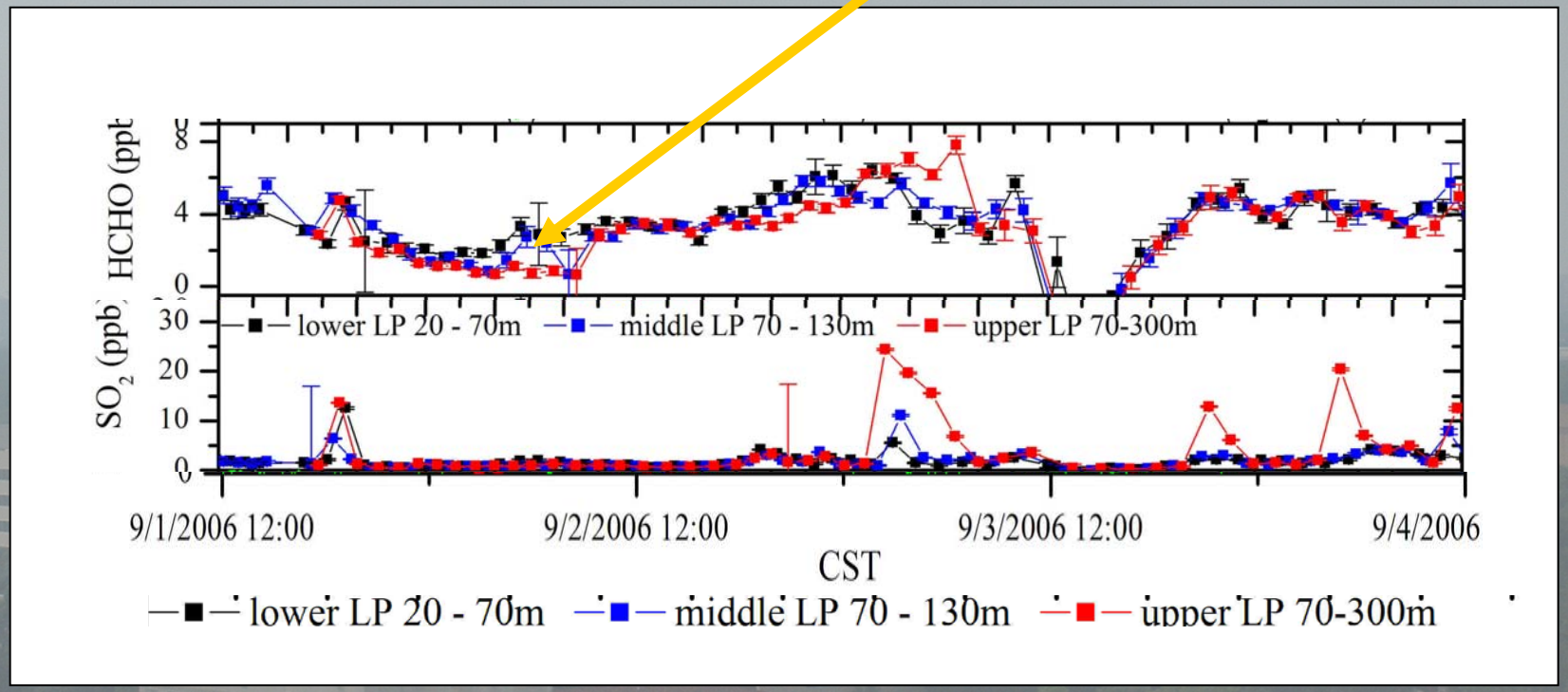


HONO shows higher values near the ground, reaching mixing ratios of up to 2 ppb.

DOAS: HCHO, SO_2

PI: Stutz (UCLA)

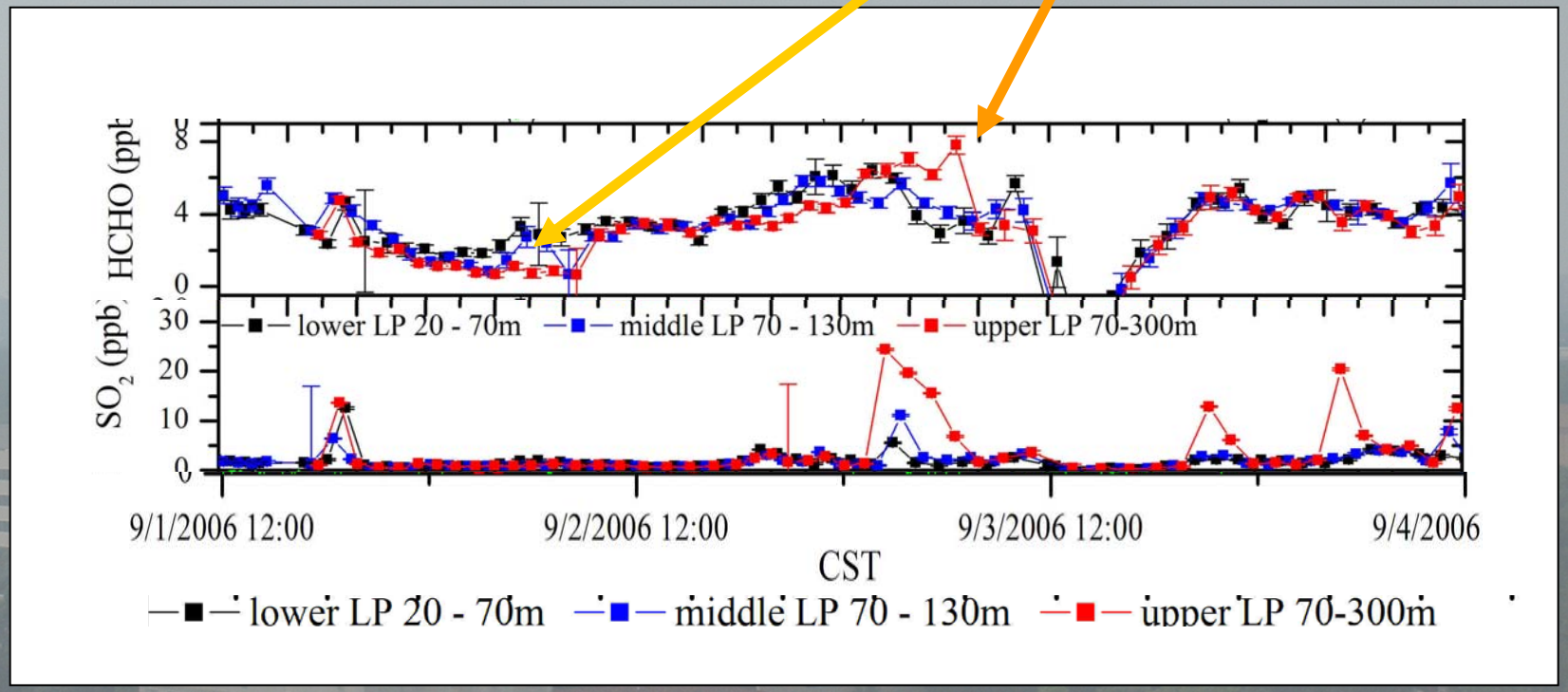
HCHO shows higher values near the ground during most nights.



DOAS: HCHO, SO_2

PI: Stutz (UCLA)

HCHO shows higher values near the ground during most nights.
Vertical gradients of HCHO mixing ratios during certain periods.



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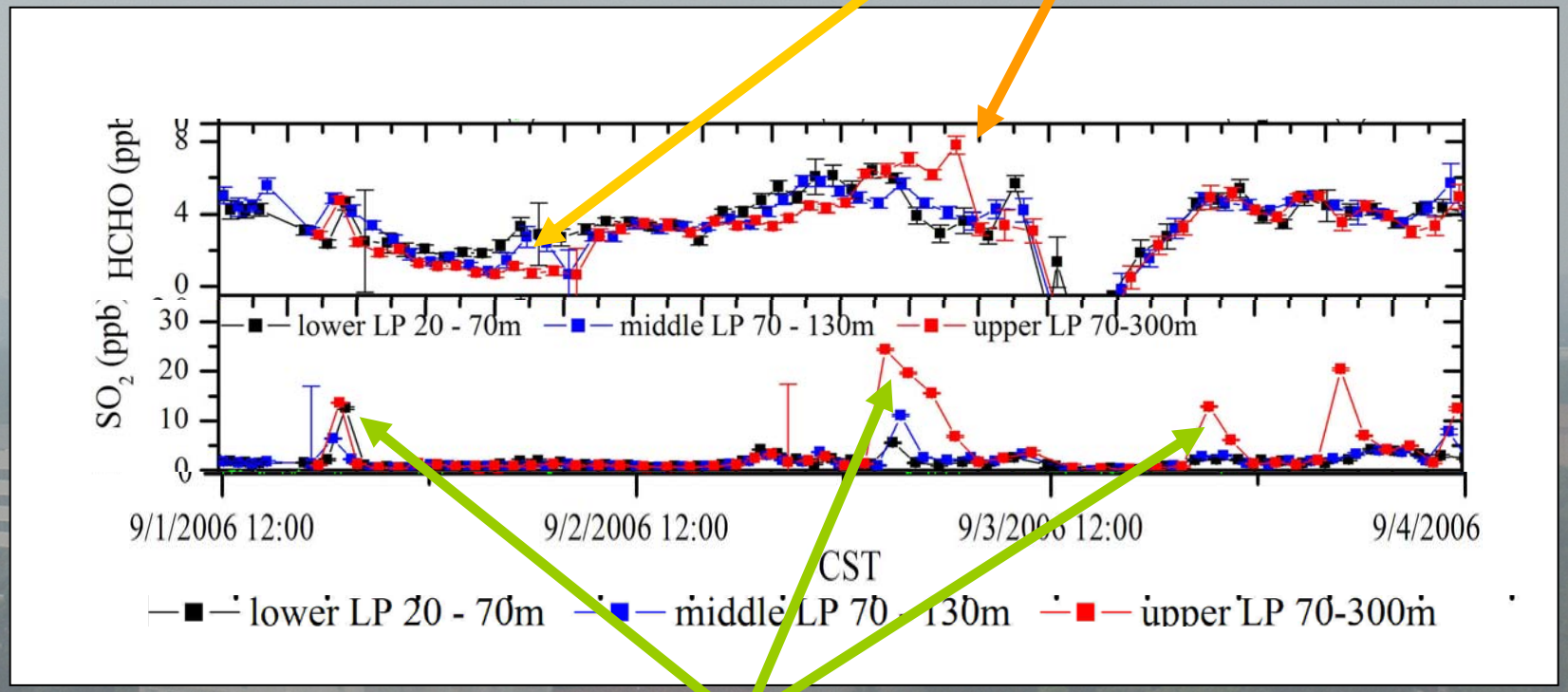
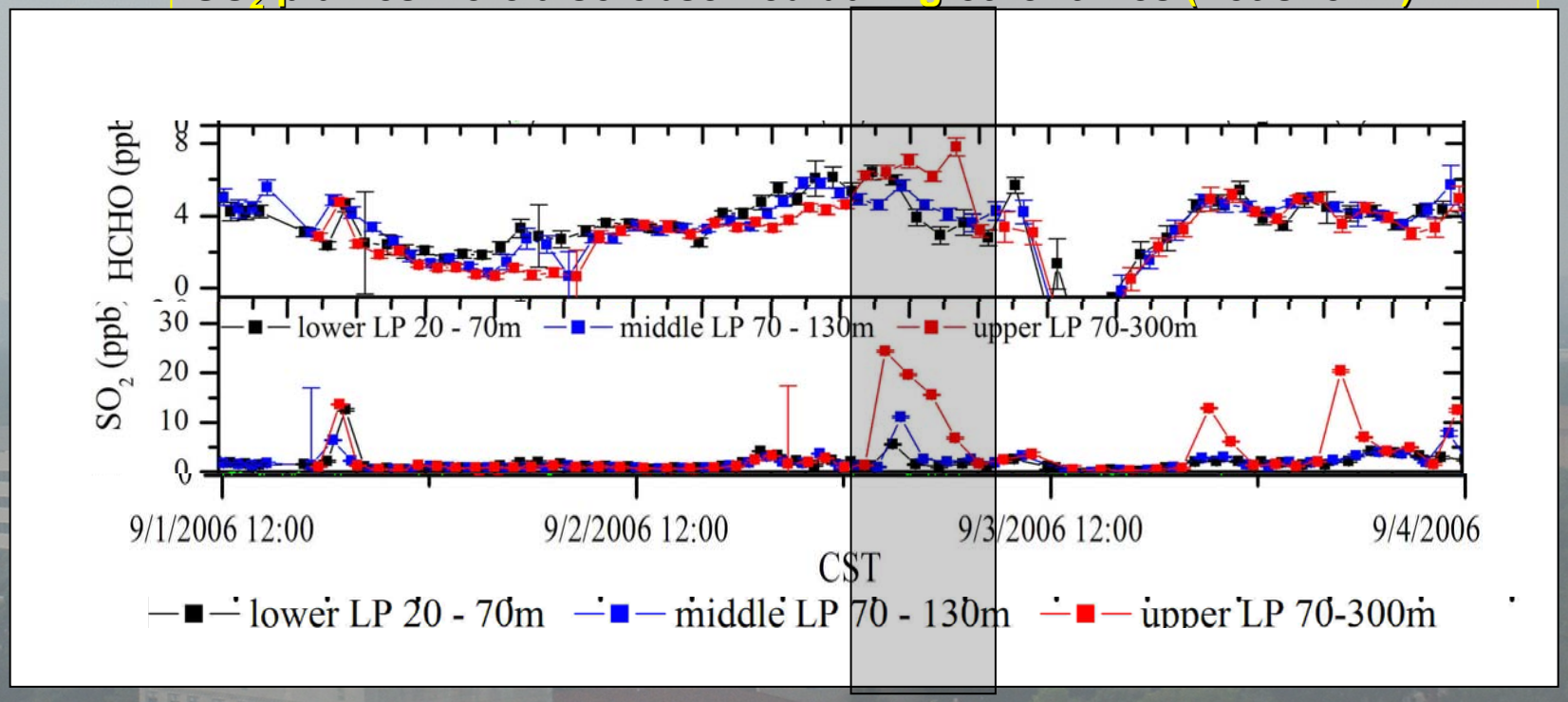


During several occasions plumes of SO_2.

DOAS: HCHO, SO_2

PI: Stutz (UCLA)

During the SO_2 plume at 9/3/06 4:00, a reversal of the HCHO profile, i.e. higher HCHO aloft, was observed. HCHO plumes correlated with SO_2 plumes were also observed during other times (not shown)



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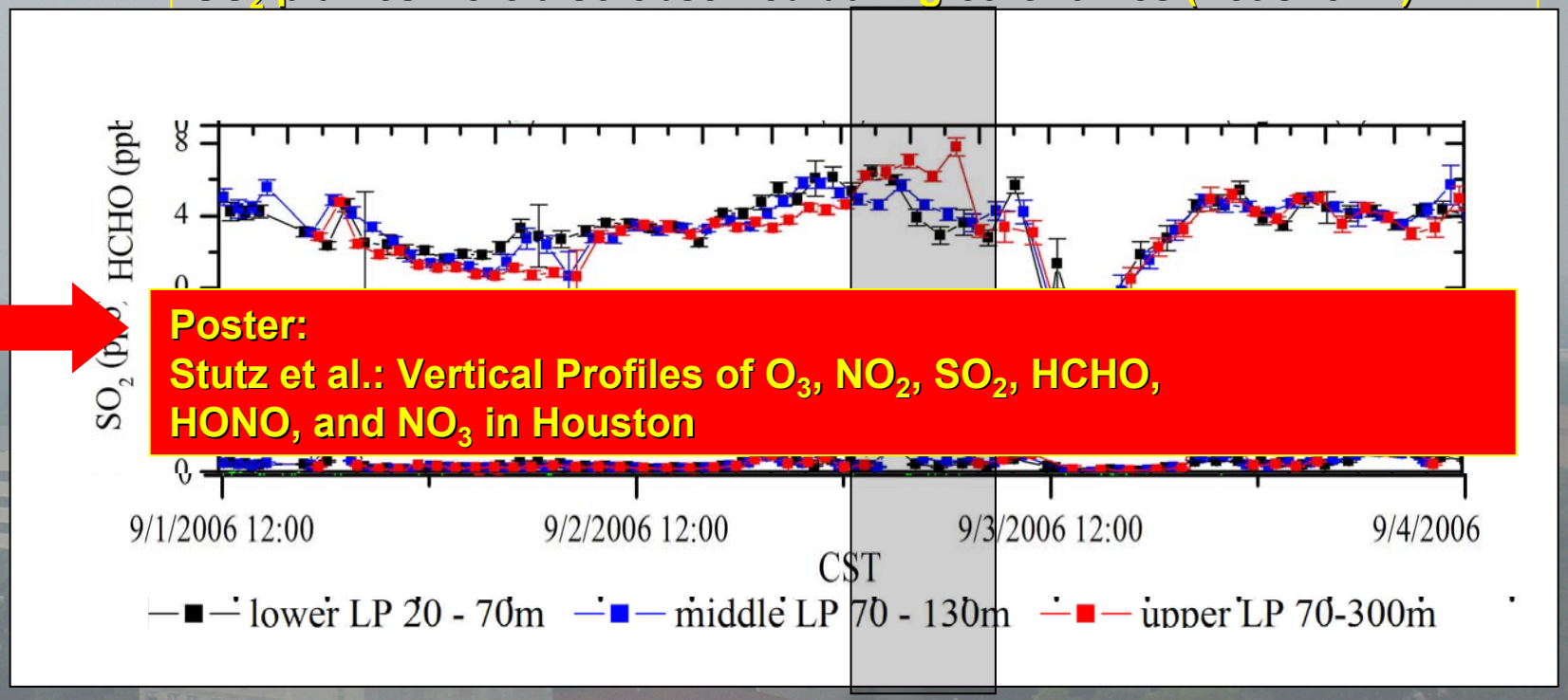


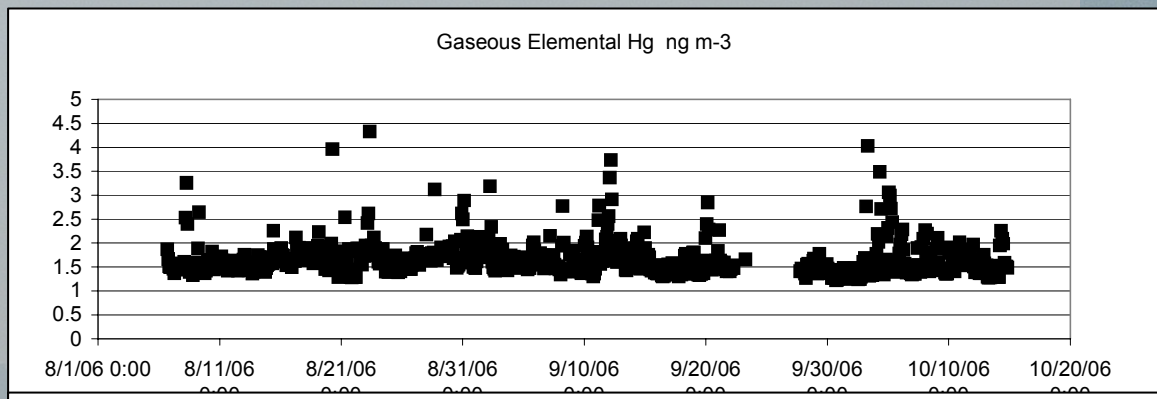
Poster:
Stutz et al.: Vertical Profiles of O_3, NO_2, SO_2, HCHO, HONO, and NO_3 in Houston

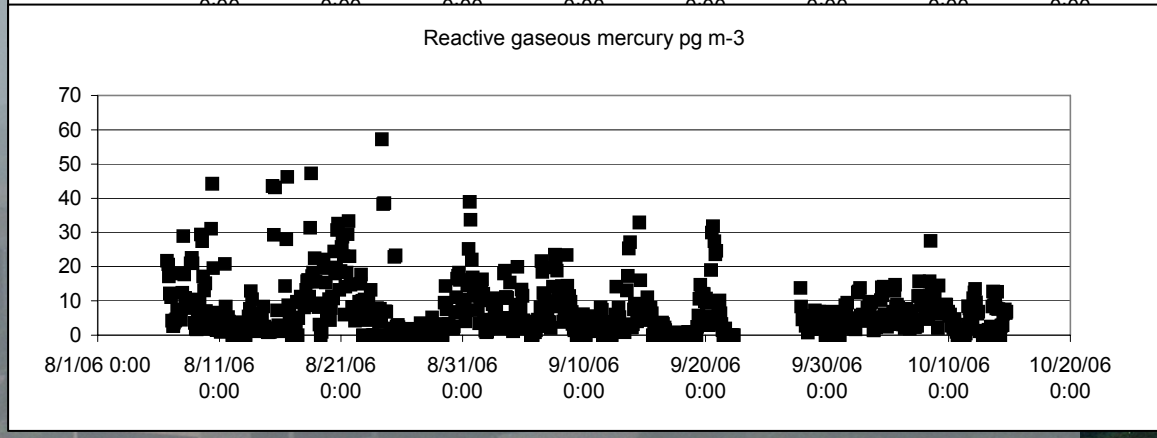
Mercury

PI:
S. Brooks
(NOAA)

gaseous elemental mercury in the typical urban range of 1.5 to 5.0 ng m^{-3}.

Reactive gaseous mercury varied from 0.0 to ~60 pg m^{-3} with typical afternoon peaks (~3pm).





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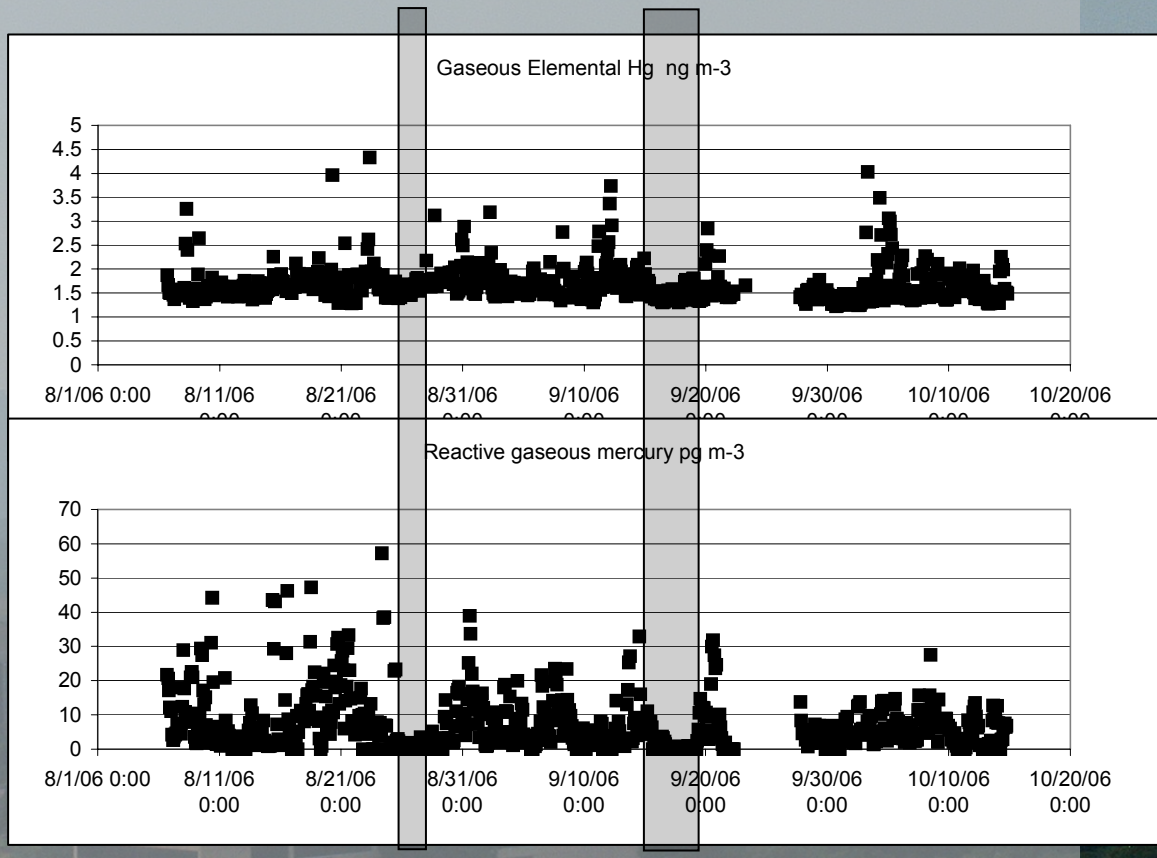


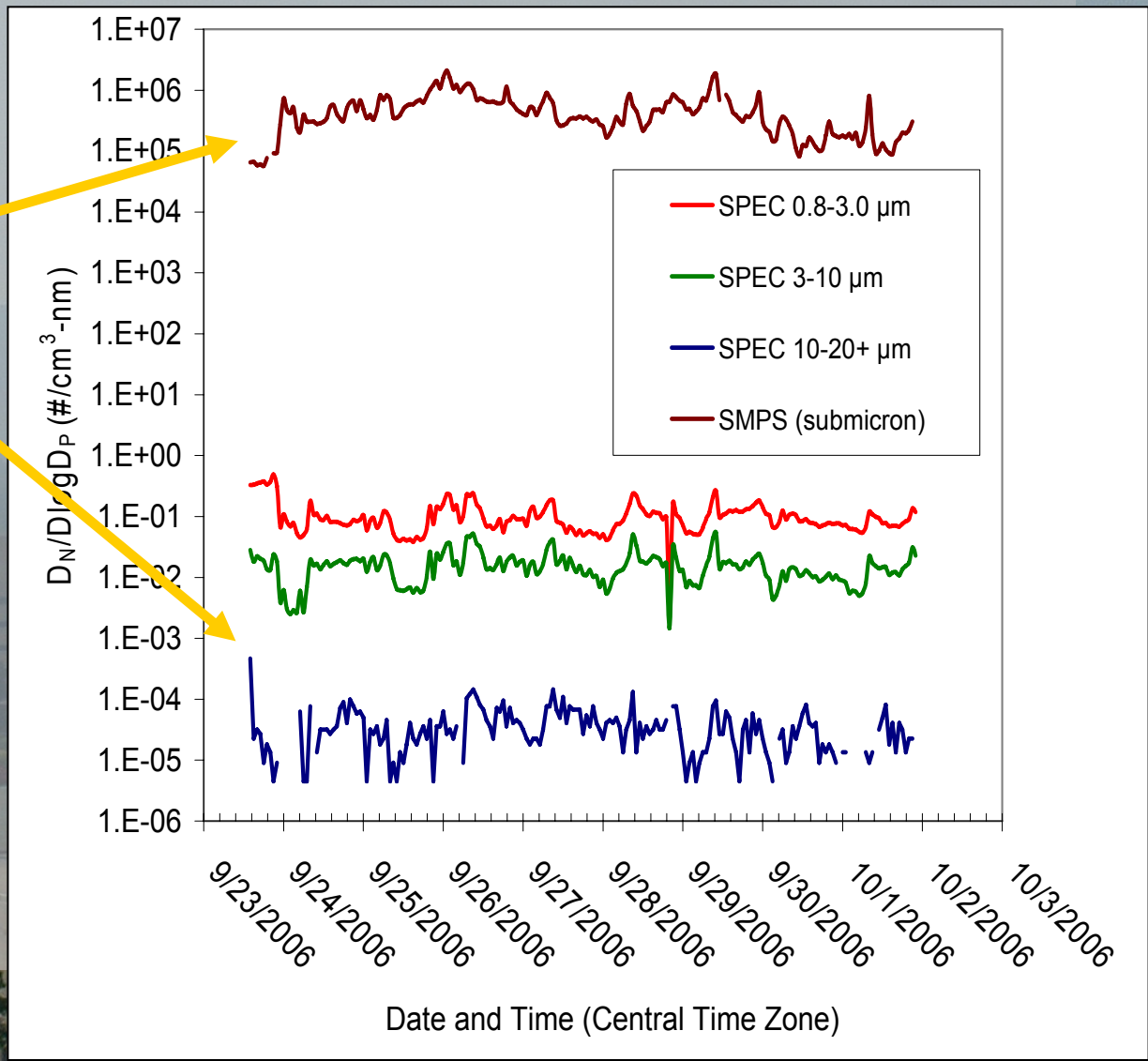
The air was extremely clean (with respect to all mercury species) on 8/26-28 and again 9/15-18.
Particulate-bound mercury levels were extremely high during the early morning hours of 8/31 (not shown).

Particle Size Distribution

PI:
S. Brooks
(Texas A&M)

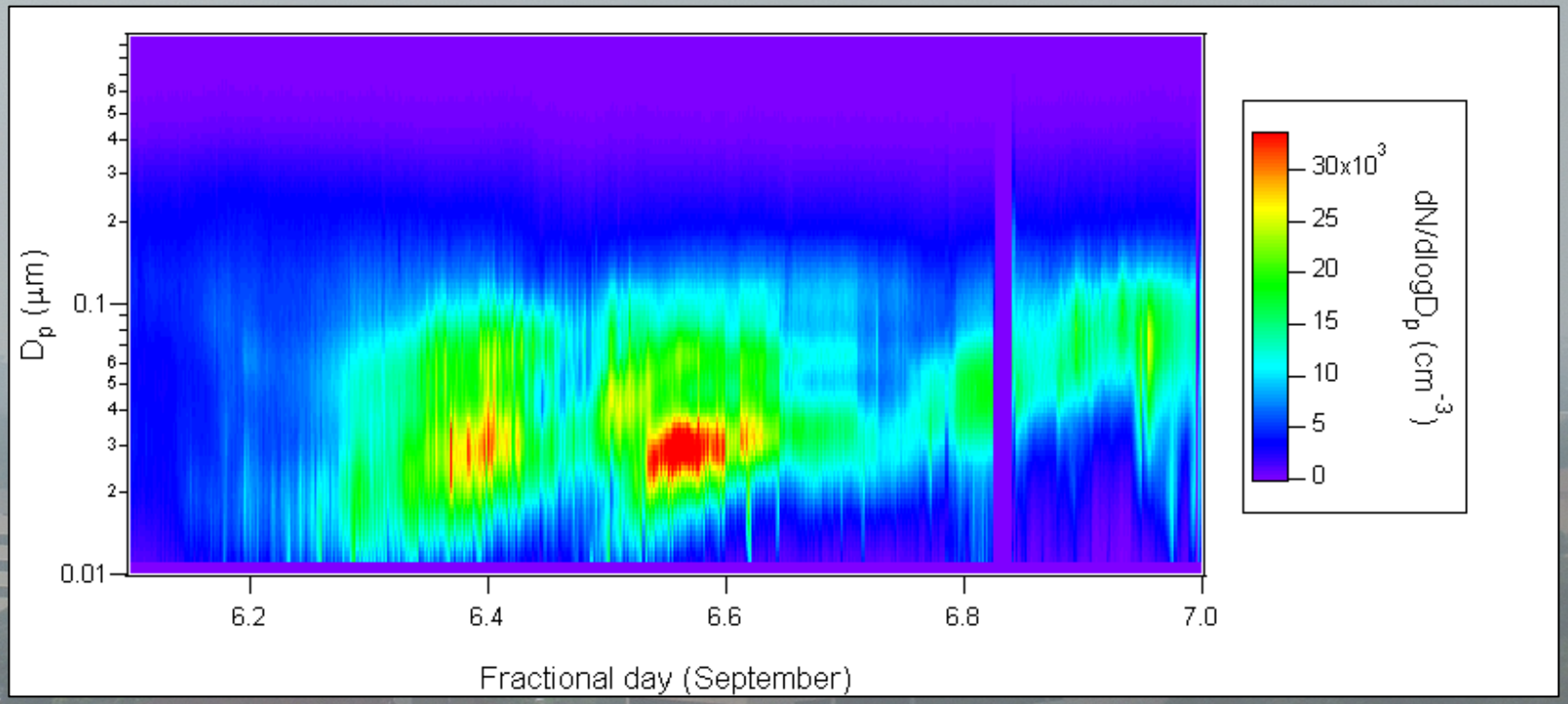
particle counts dominated by submicron particles

also significant numbers of large particles (≥10 µm)



Particle Growth

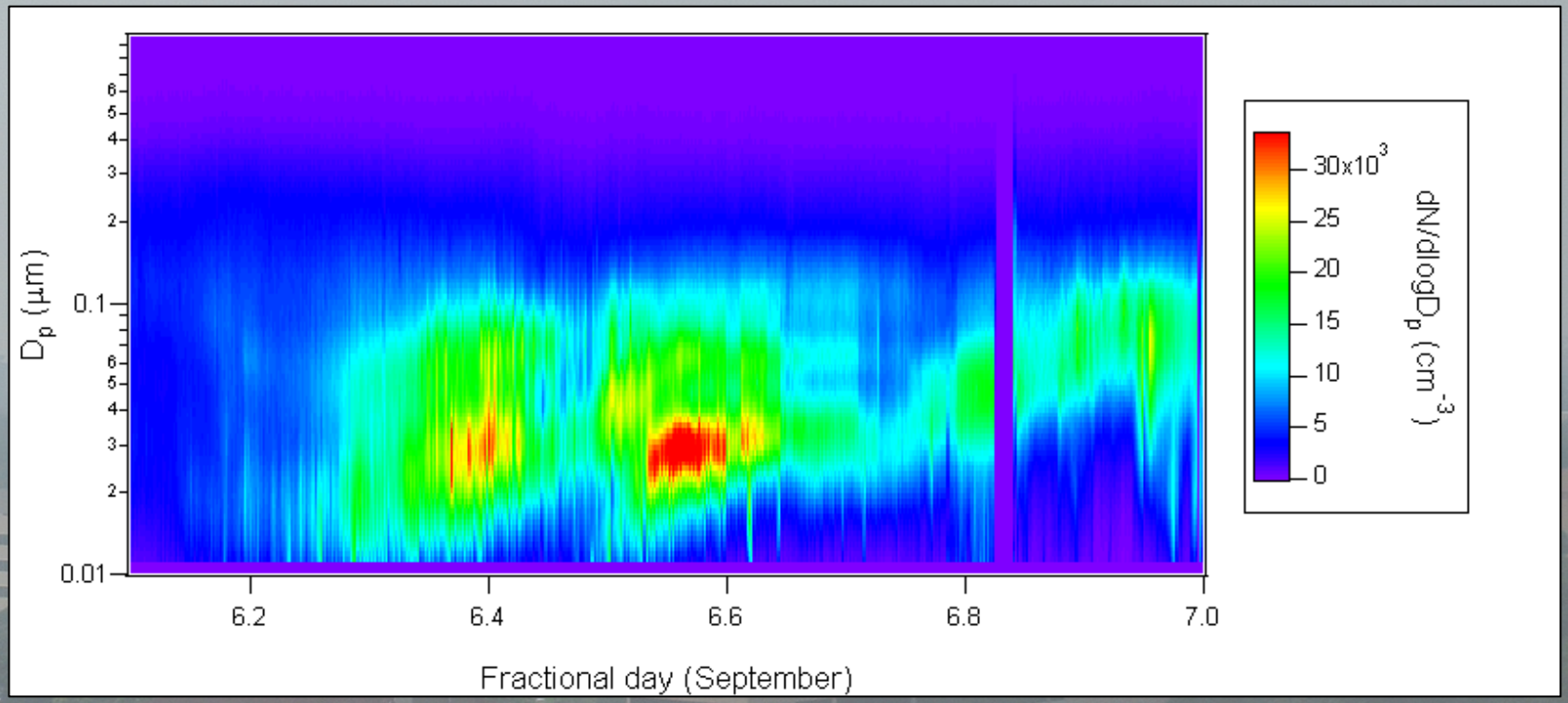
PI:
D. Collins
(Texas A&M)



Particles formed through nucleation events or directly emitted were observed to grow over a time scale of a few hours.

Particle Growth

PI:
D. Collins
(Texas A&M)



bimodal hygroscopic growth factor distributions:
-less hygroscopic mode believed to be primarily comprised of *primary organic* and *soot particles*
- a more hygroscopic mode contains *sulfate particles*.

Particle Growth

PI:
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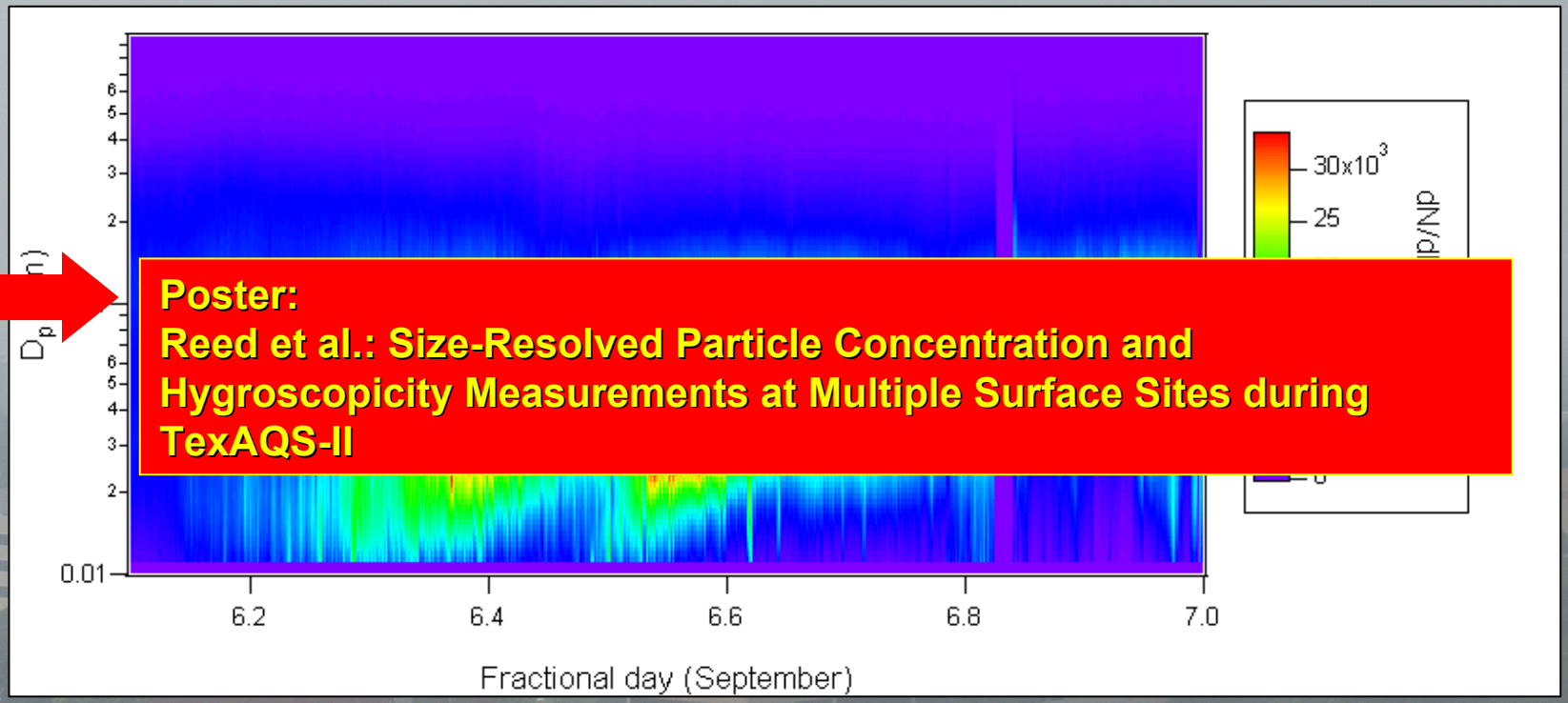
(Texas A&M)



Poster:
Reed et al.: Size-Resolved Particle Concentration and Hygroscopicity Measurements at Multiple Surface Sites during TexAQS-II

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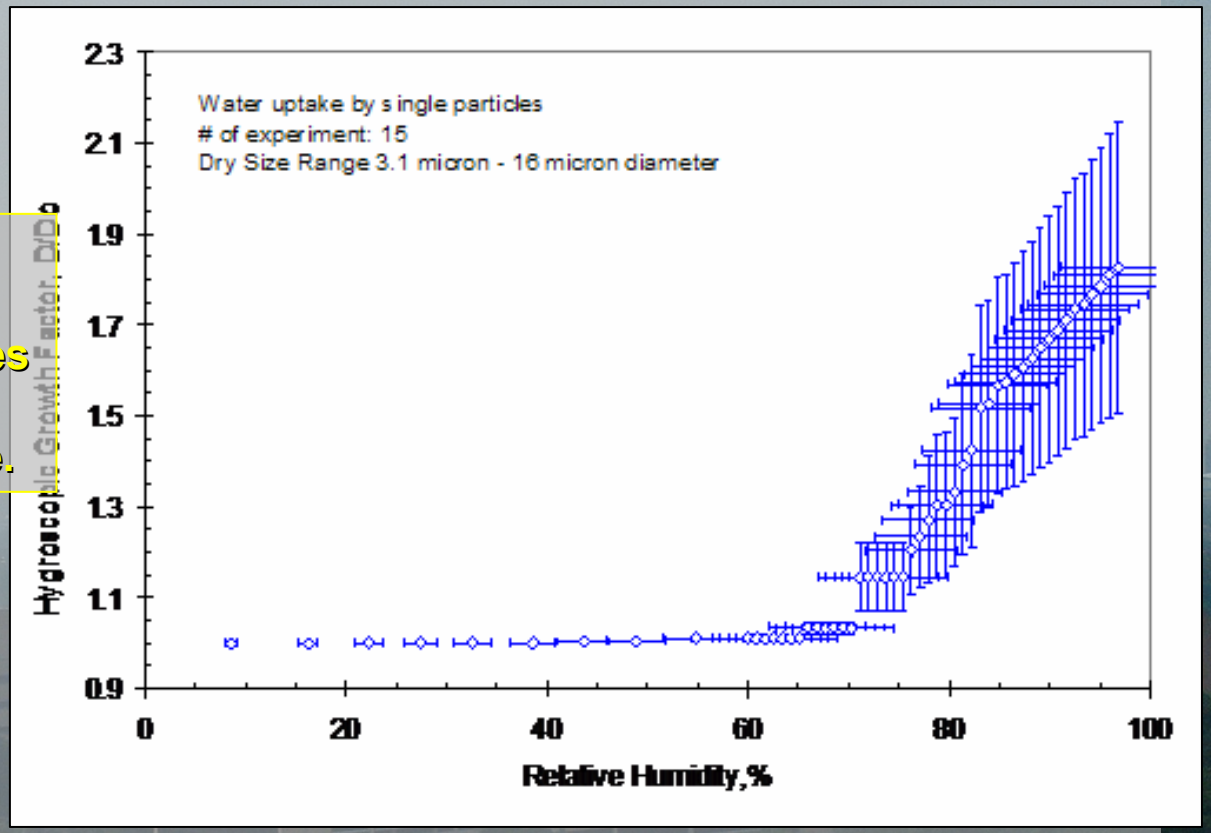
- a more hygroscopic mode contains *sulfate particles*.

Single Particle Hygroscopicity Measurements

PI:
S. Brooks
(Texas A&M)

Single particle hygroscopicity measurements conducted on time resolved impactor samples using an Environmental Scanning Electron Microscope.



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PI:
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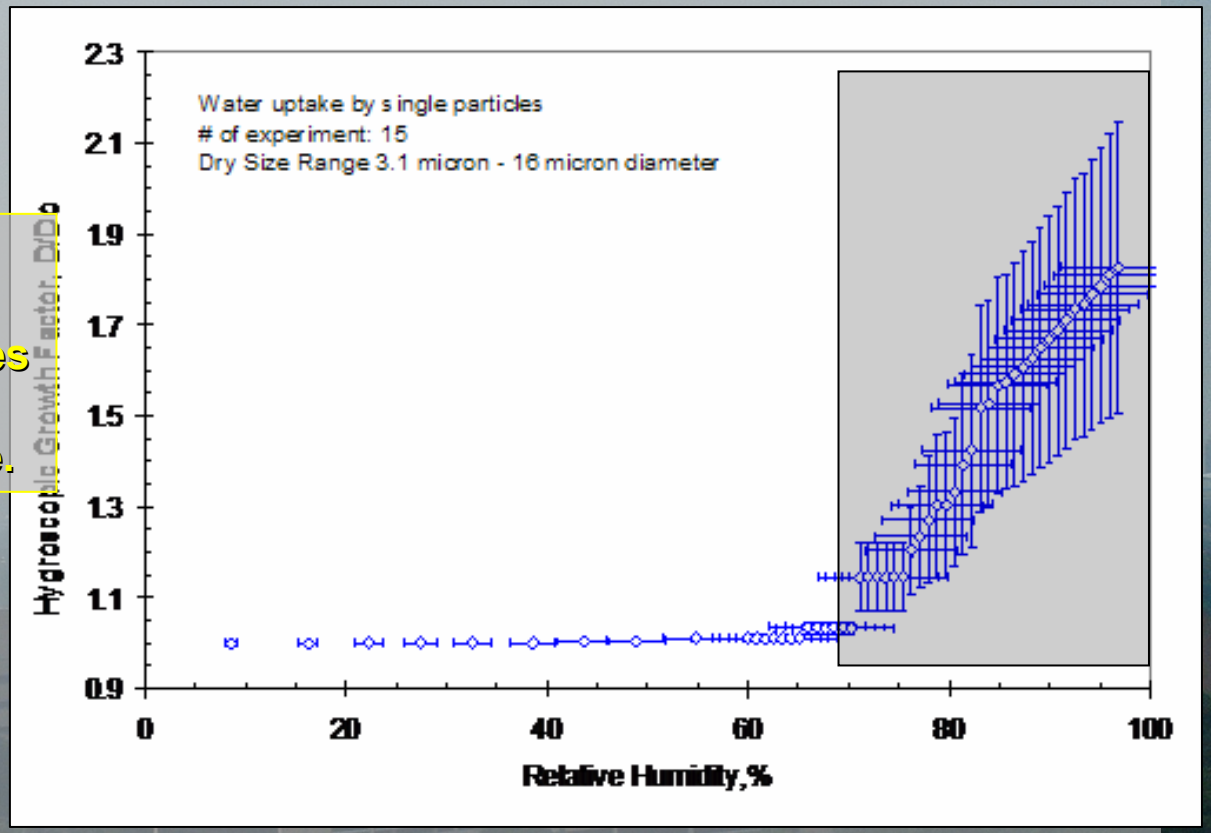
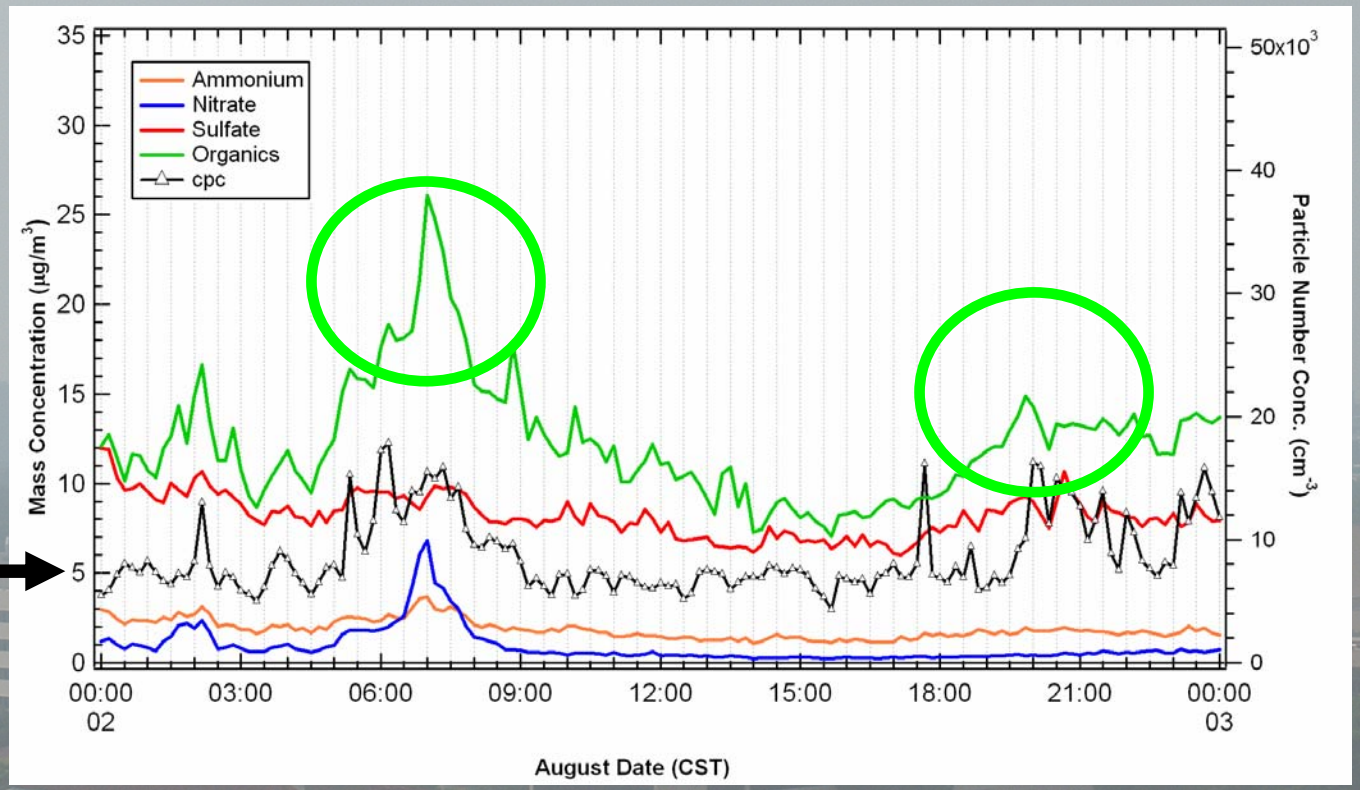


Particles were reasonably hygroscopic, taking up significant amounts of water at relative humidities above 70% and increasing to ~180 % of their original size at RHs above 90%.

Particle Composition

PI:
R. Griffin (U New Hampshire)



Mass concentrations dominated by organic material and sulfate aerosol. Organic aerosol concentrations show a large increase in the morning and again late in the day.

Total number concentrations follow organic aerosol species.

Particle Composition

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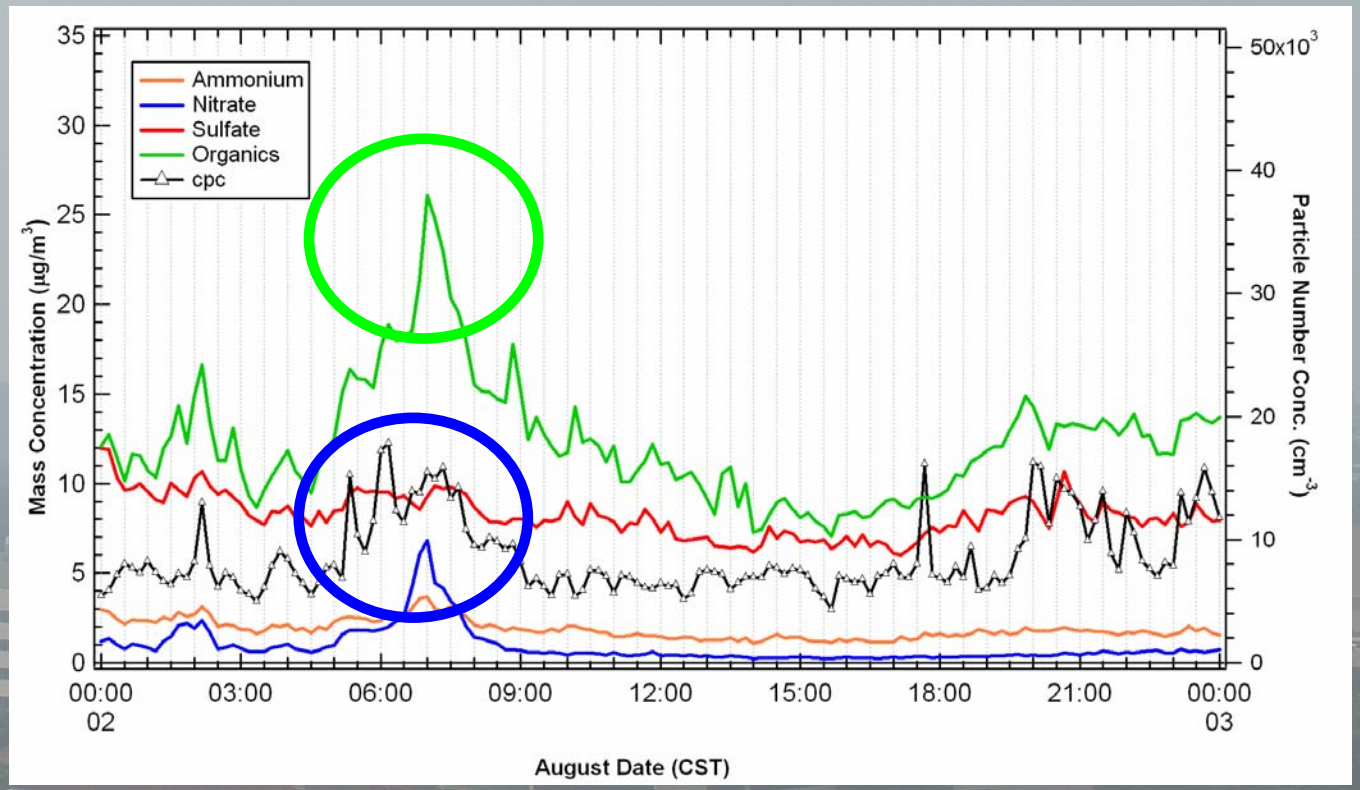
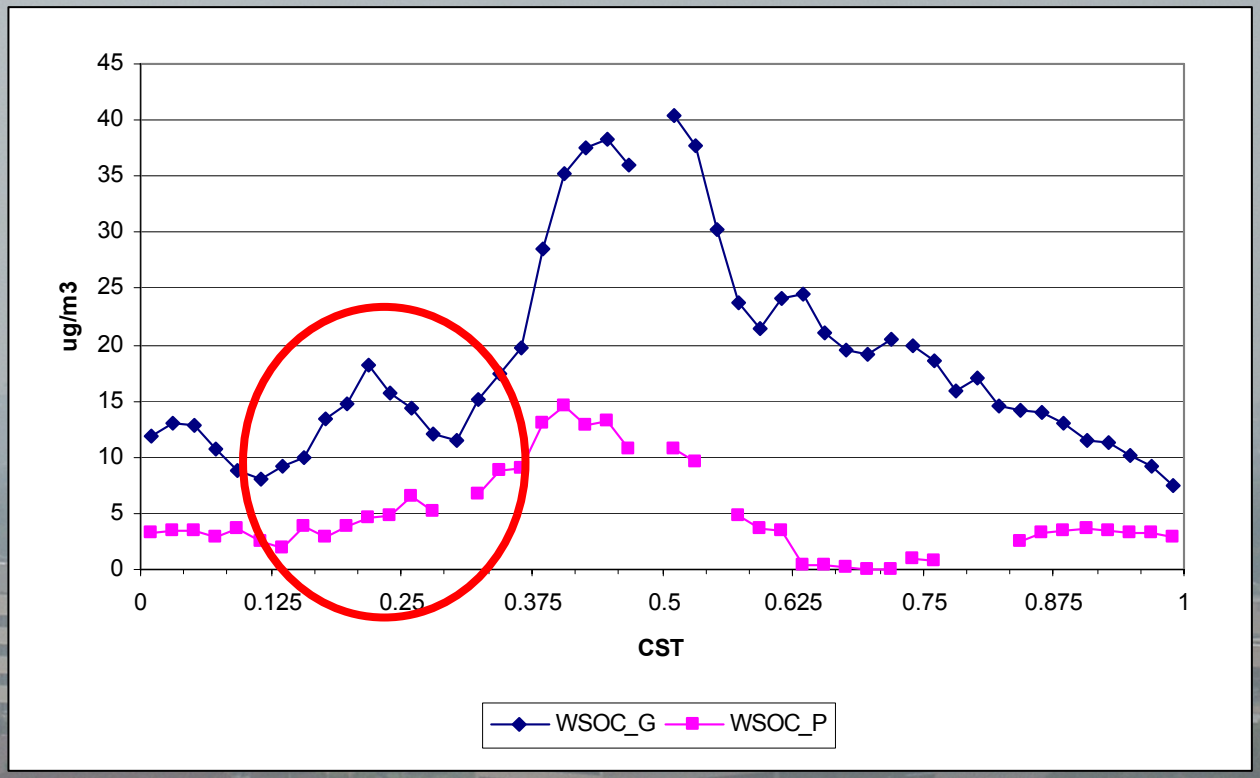
R. Griffin (U New Hampshire)



Large spike in nitrate aerosol that appears to be associated with organic aerosol material.
Increase corresponds to a rapid decrease in gas-phase concentrations of nitric acid.

Water soluble gases and aerosols

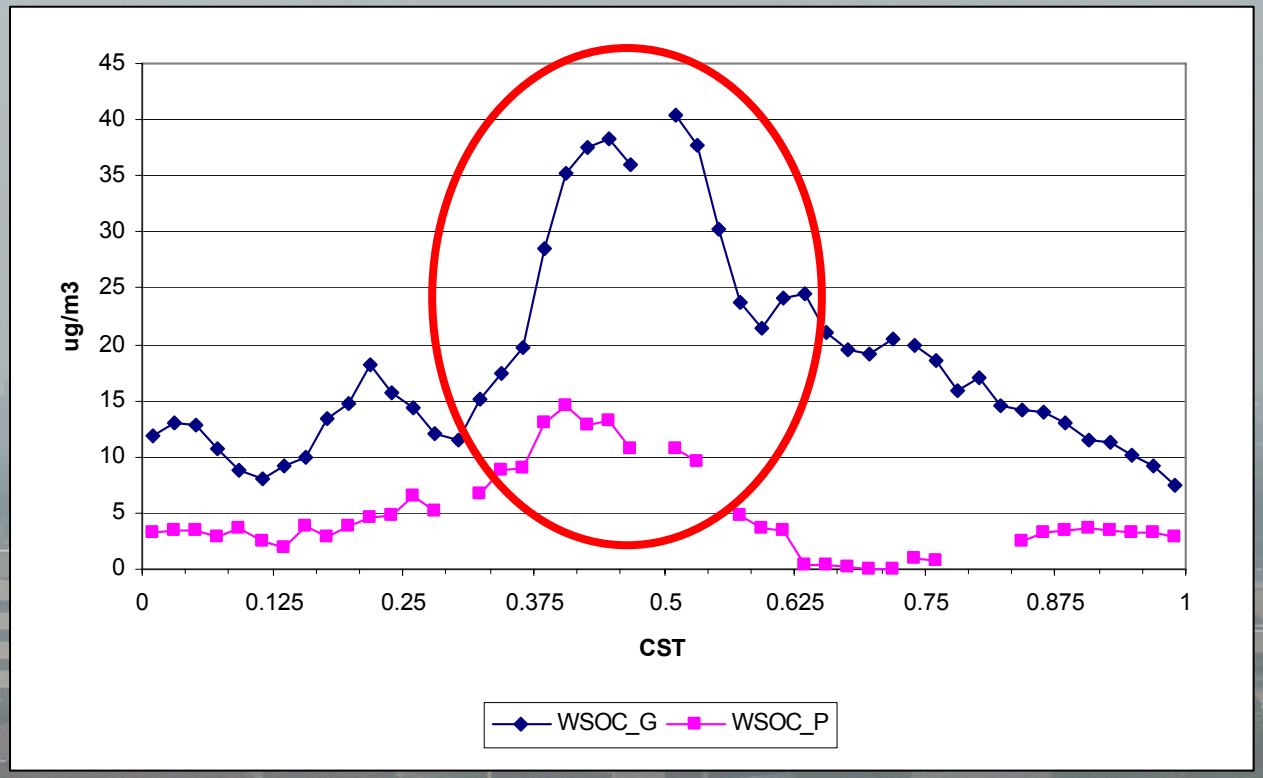
PI:
J. Dibb
(U New Hampshire)



Small peak in the water soluble gases at 5 am
Wind direction indicates Ship Channel as possible source region.
However, also rush hour traffic impact.

Water soluble gases and aerosols

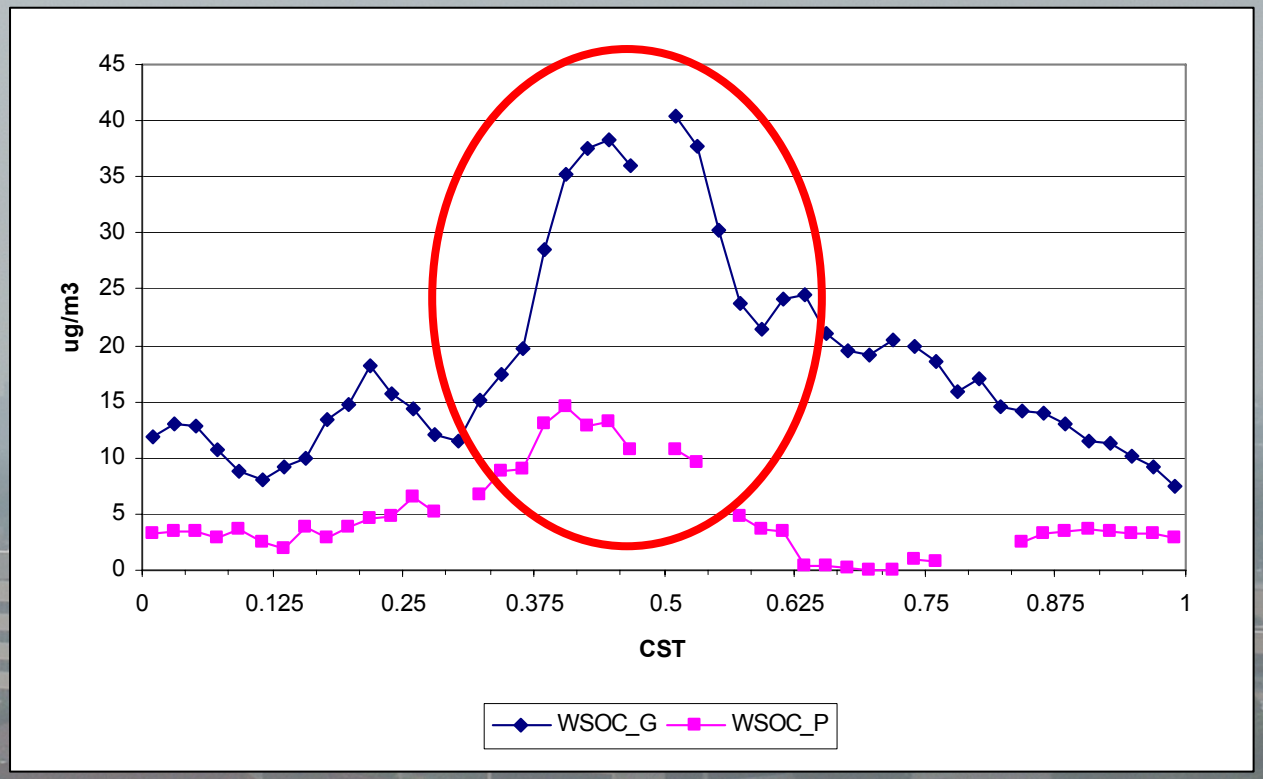
PI:
J. Dibb
(U New Hampshire)



Water soluble gas and aerosol concentrations increase rapidly as the sun rises (gas peak of 40 µg/m^3 at noon is very high compared to other locations)

Water soluble gases and aerosols

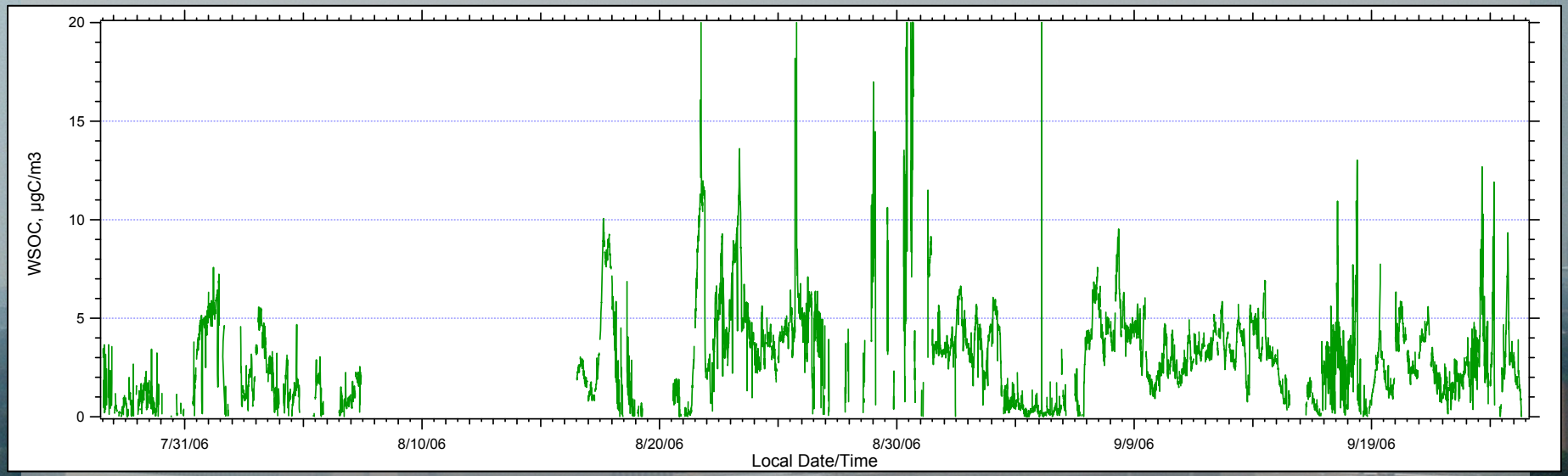
PI:
J. Dibb
(U New Hampshire)



Pattern in the concentration of water soluble organics compares well with AMS data. Midday peak appears to be due to oxidation of primary organic emissions, which increases the solubility of the organic compounds.

On-Line Measurements of PM2.5 Water-Soluble Organic Carbon

PI:
R. Weber
(Gerogia Tech)



Time series of the water-soluble fraction of PM2.5 organic carbon.

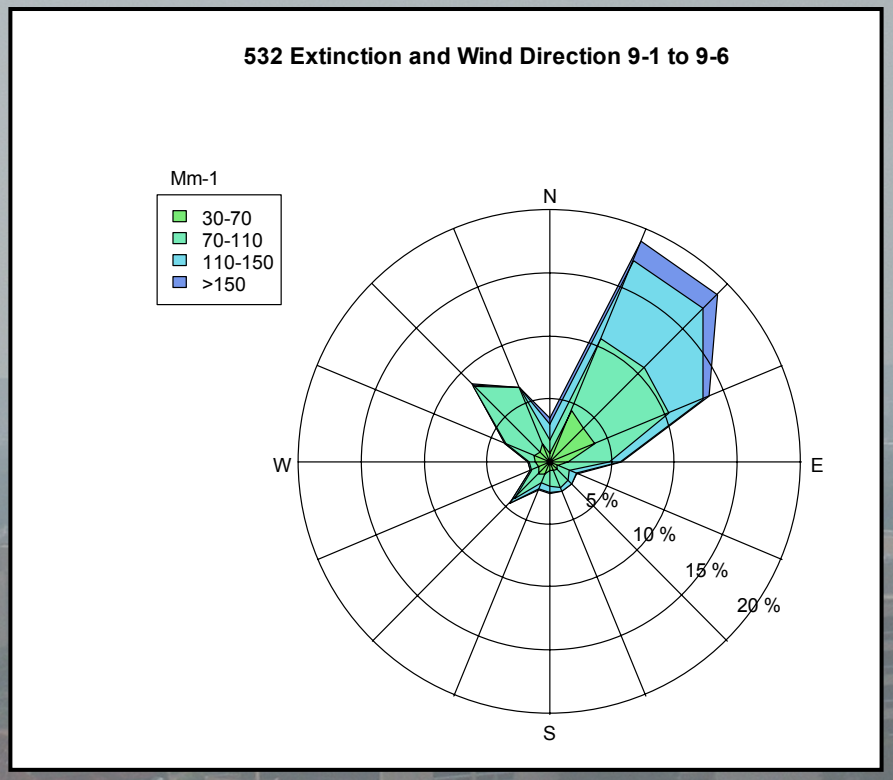
Two main sources for WSOC:

(i) biomass burning emissions

(ii) secondary organic aerosol formation.

Aerosol optical properties

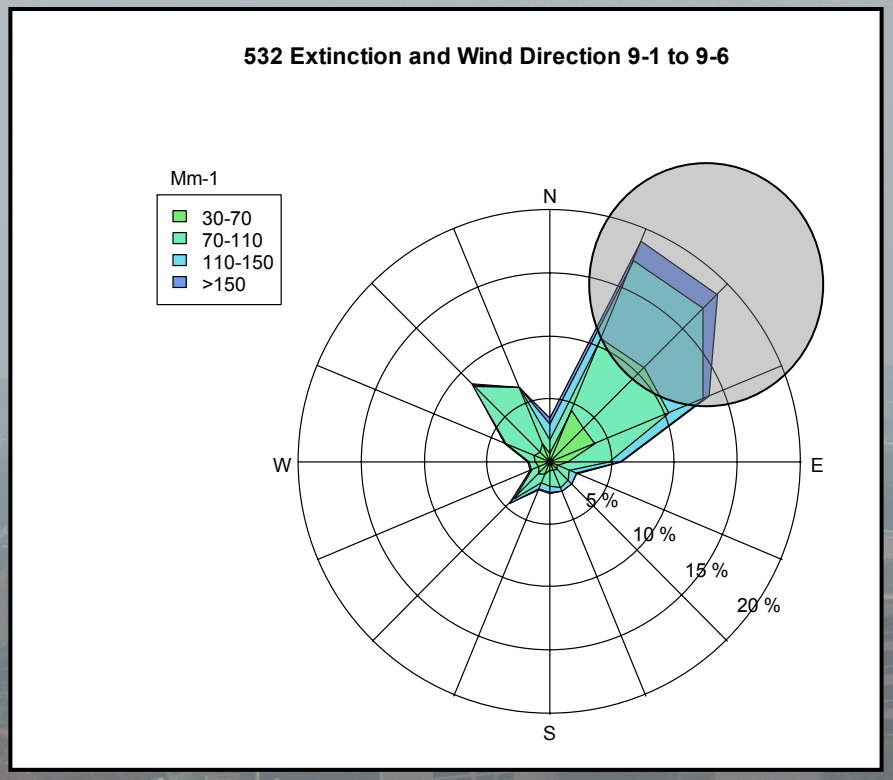
PI:
D. Atkinson
(Portland State U)



No clear indication of a single dominant source of PM in Houston.

Aerosol optical properties

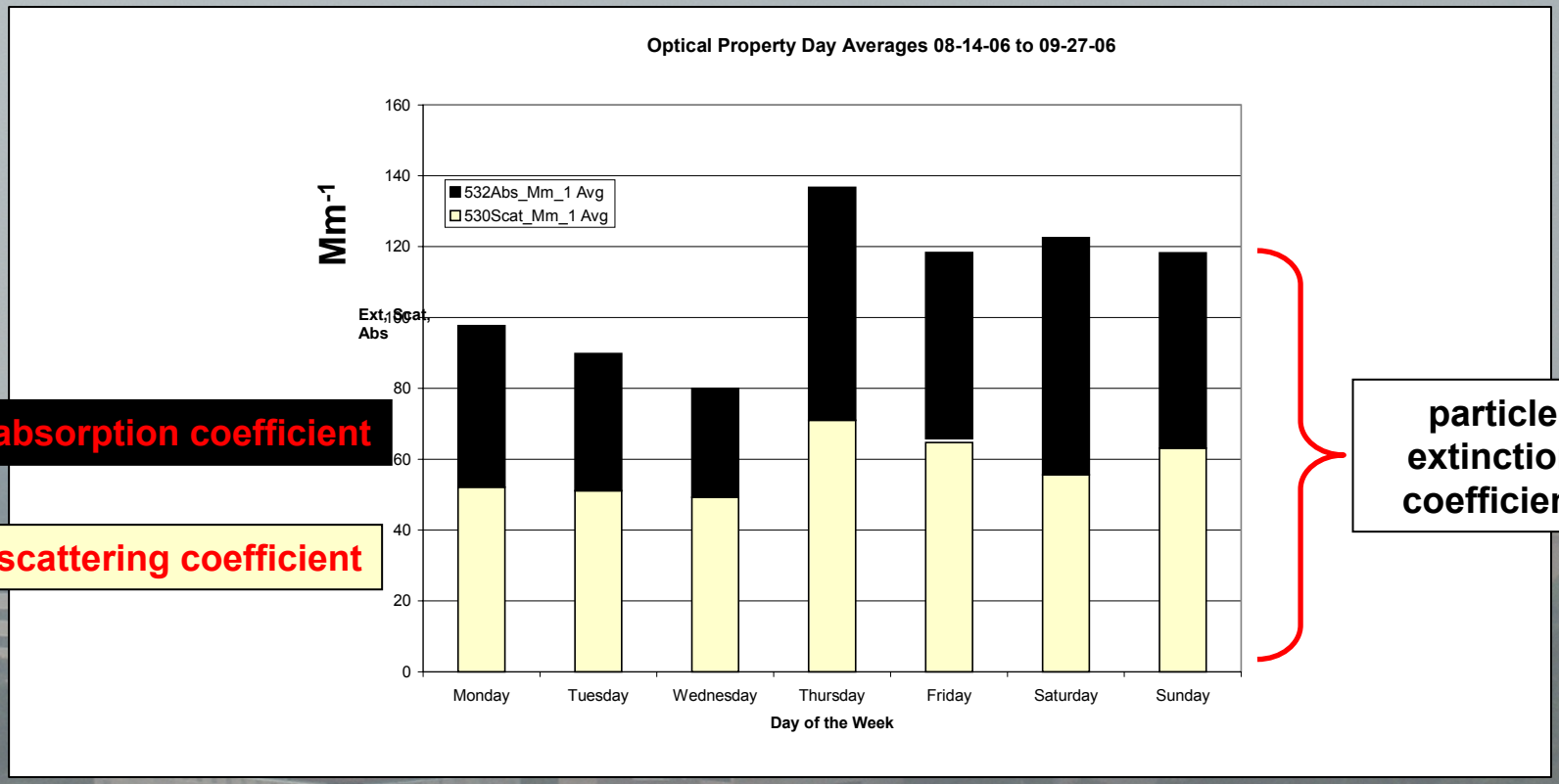
PI:
D. Atkinson
(Portland State U)



However, indications that much of PM, and primary and secondary chemical contaminants originate in the ship channel area. Episodically, emissions from local industries as well as longer range transport of PM often contributed dramatically to the total light.

Aerosol optical properties

PI:
D. Atkinson
(Portland State U)



particle absorption coefficient

particle scattering coefficient

particle extinction coefficient

Aerosol optical properties

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D. Atkinson
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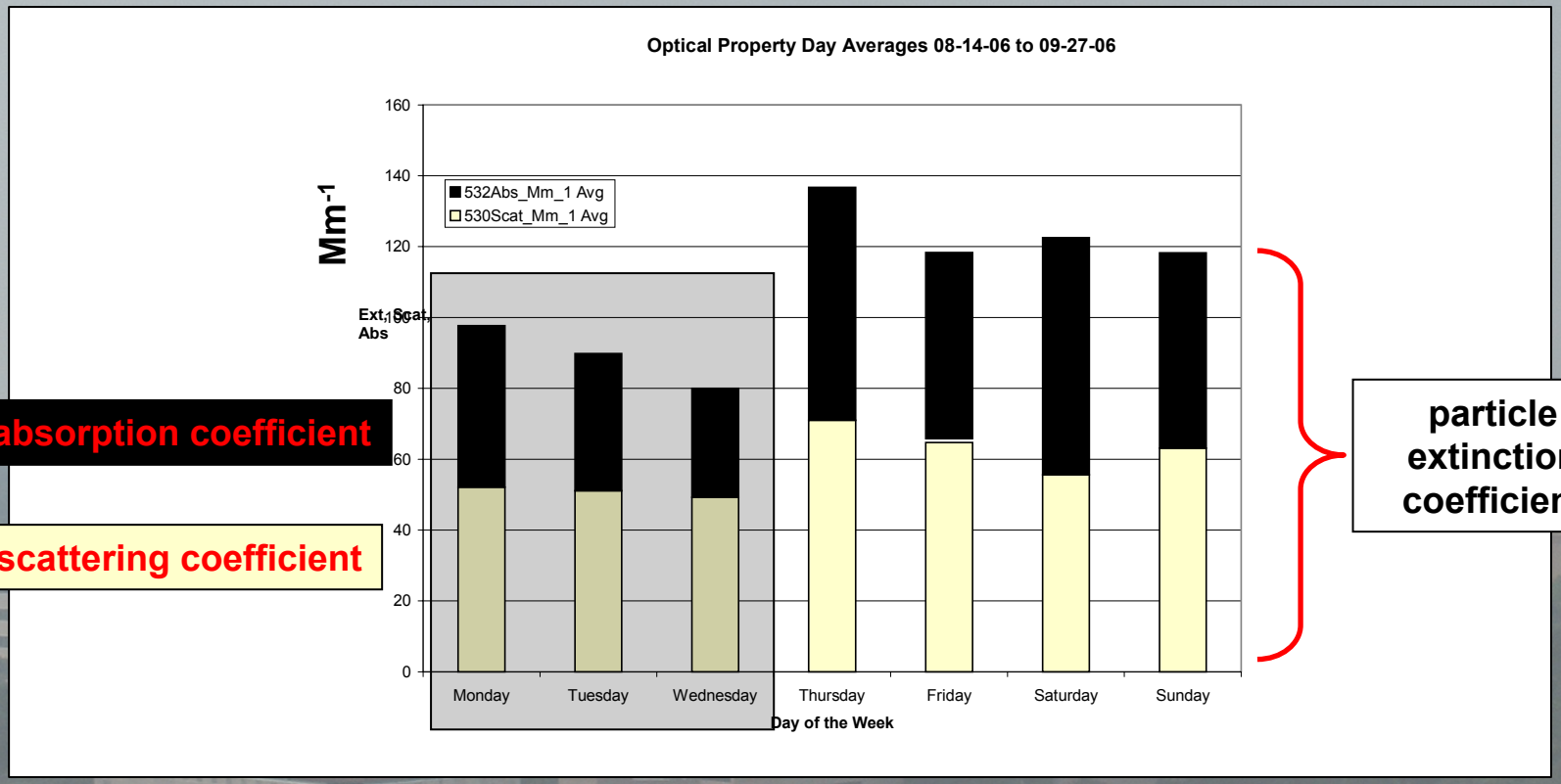


particle absorption coefficient

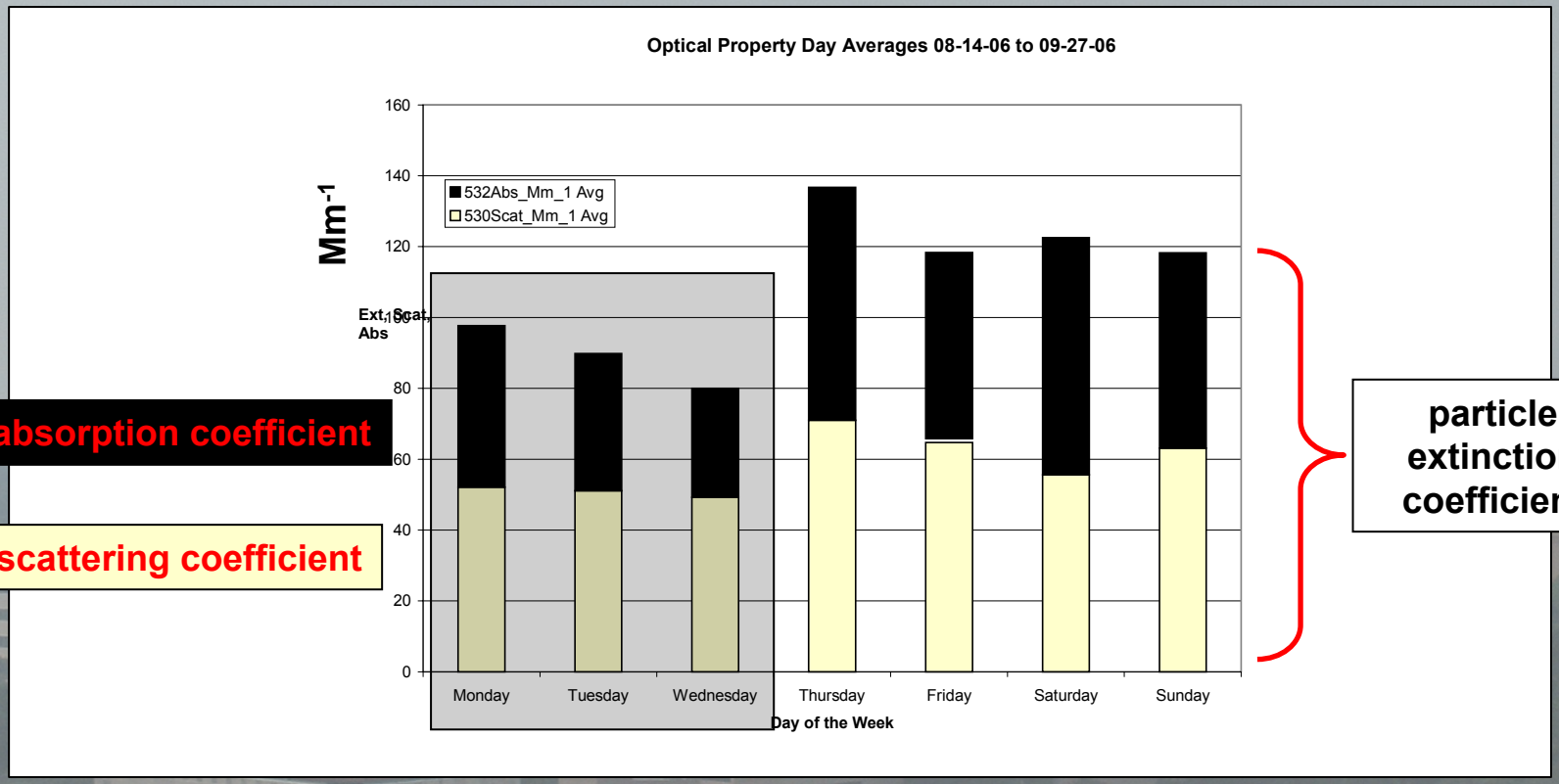
particle scattering coefficient

particle extinction coefficient

Weekly pattern of aerosol optical extinction (and scattering) shows a Monday-Wednesday "weekend" signal.

Aerosol optical properties

PI:
D. Atkinson
(Portland State U)



particle absorption coefficient

particle scattering coefficient

particle extinction coefficient

Sporting events and other recreational activities responsible?
The low levels of PM on Monday, Tuesday, and Wednesday are not as easy to rationalize.

Aerosol optical properties

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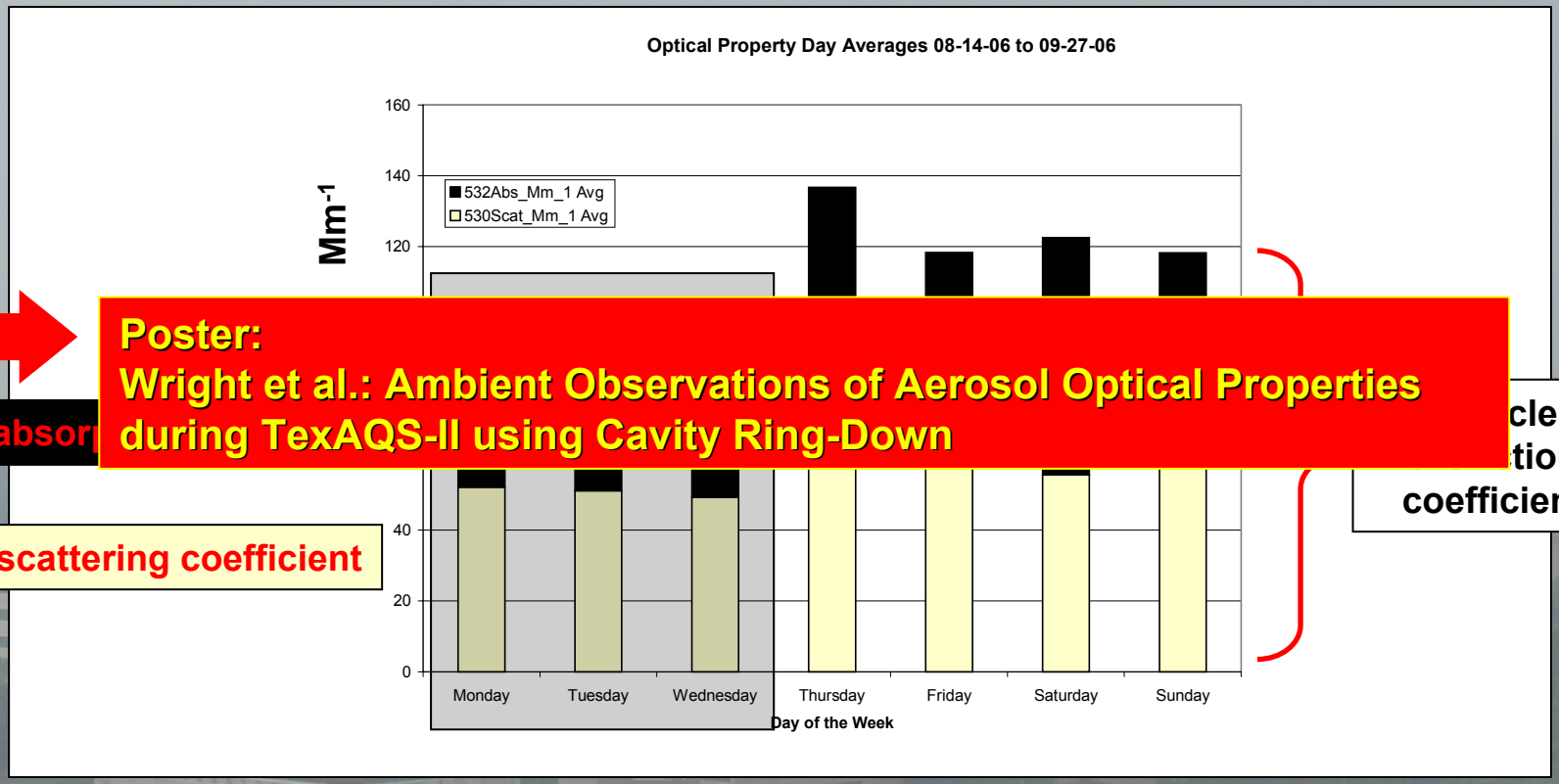
D. Atkinson
(Portland State U)



Poster:
Wright et al.: Ambient Observations of Aerosol Optical Properties during TexAQS-II using Cavity Ring-Down

particle absorp

particle scattering coefficient

cle
tion
coefficient

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The low levels of PM on Monday, Tuesday, and Wednesday are not as easy to rationalize.

Radiation Measurements

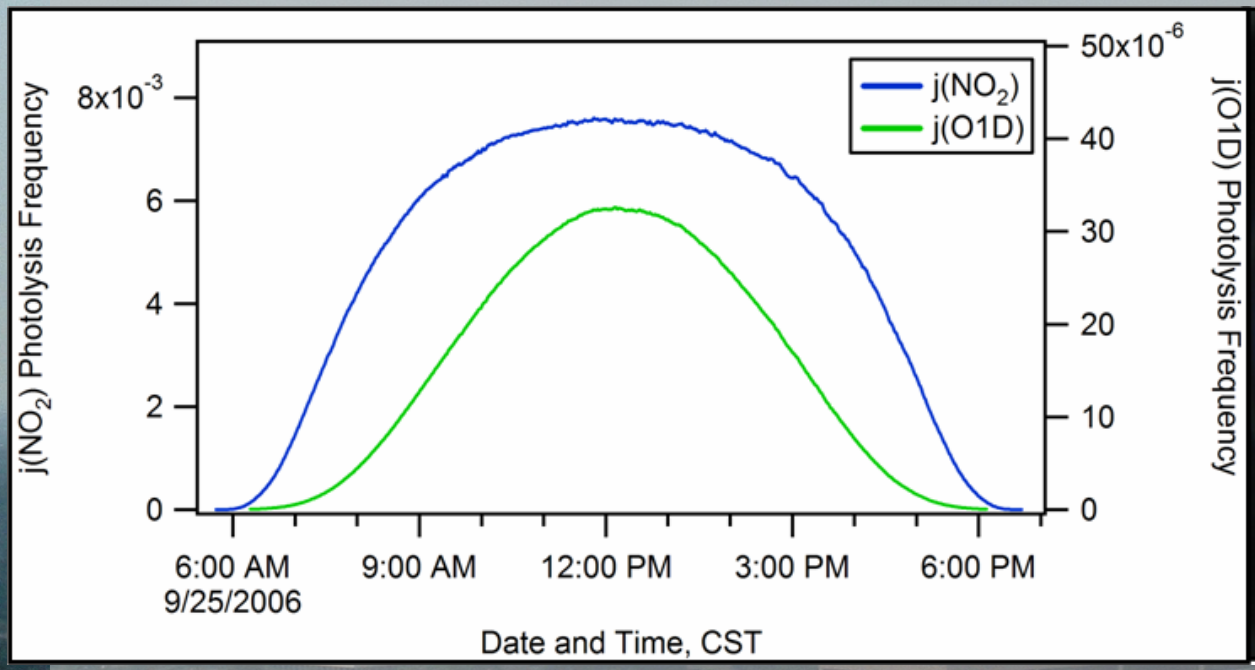
PI:
B. Lefer
(UH)

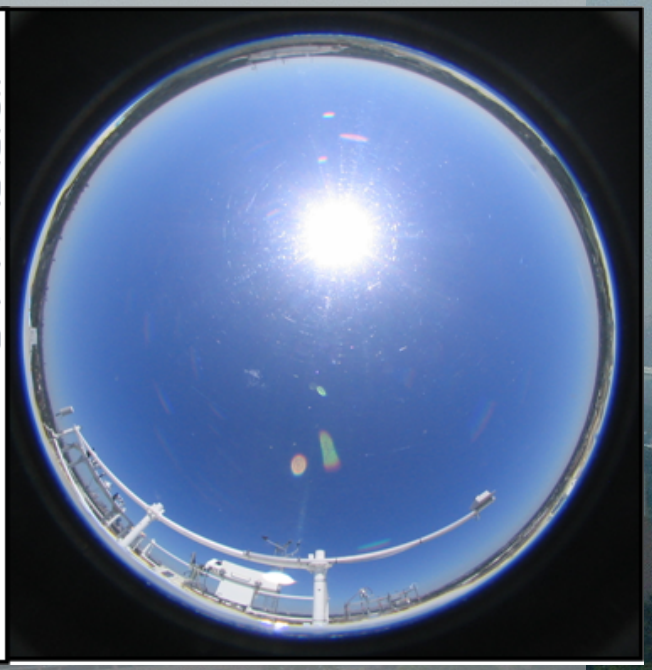
$j[O_3+h\nu \rightarrow O_2+O(1D)]$	$j[CHOCHO+h\nu \rightarrow HCO+HCO]$
$j[NO_2+h\nu \rightarrow NO+O(3P)]$	$j[CH_3COCHO+h\nu \rightarrow products]$
$j[N_2O_5+h\nu \rightarrow NO_3+NO+O(3P)]$	$j[CH_3COCH_3+h\nu \rightarrow products]$
$j[N_2O_5+h\nu \rightarrow NO_3+NO_2]$	$j[CH_3OOH+h\nu \rightarrow CH_3O+OH]$
$j[HOOH+h\nu \rightarrow 2OH]$	$j[CH_3ONO_2+h\nu \rightarrow CH_3O+NO_2]$
$j[HONO+h\nu \rightarrow OH+NO]$	$j[PAN+h\nu \rightarrow products]$
$j[HNO_3+h\nu \rightarrow OH+NO2]$	$j[CH_3CH_2CH_2CHO+h\nu \rightarrow C_3H_7+HCO]$
$j[HCHO+h\nu \rightarrow H+HCO]$	$j[CH_3CH_2CH_2CHO+h\nu \rightarrow C_2H_4+CH_2CHOH]$
$j[HCHO+h\nu \rightarrow H_2+CO]$	$j[CH_3COCH_2CH_3+h\nu \rightarrow products]$
$j[CH_3CHO+h\nu \rightarrow CH_3+HCO]$	$j[HO_2NO_2+h\nu \rightarrow HO_2+NO_2]$
$j[CH_3CHO+h\nu \rightarrow CH_4+CO]$	$j[HO_2NO_2+h\nu \rightarrow OH+NO_3]$
$j[C_2H_5CHO+h\nu \rightarrow C_2H_5+HCO]$	$j[CH_3CH_2ONO_2+h\nu \rightarrow products]$
$j[CHOCHO+h\nu \rightarrow products]$	

Photolysis frequencies currently calculated

Radiation Measurements

PI:
B. Lefer
(UH)

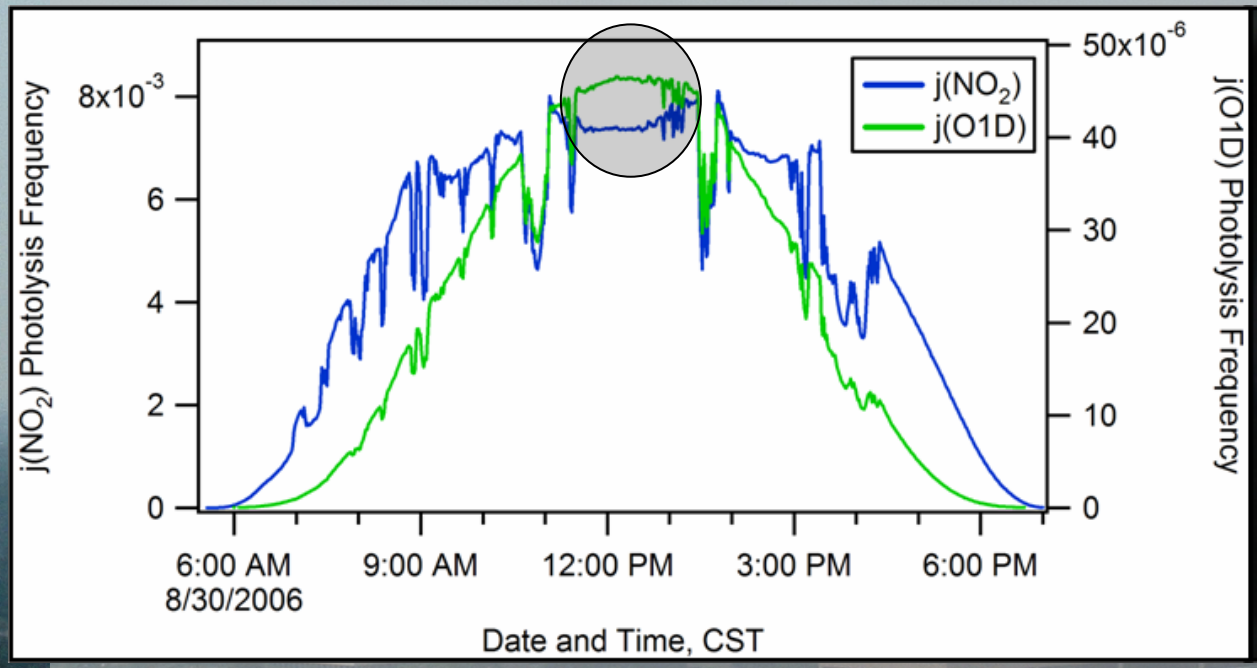


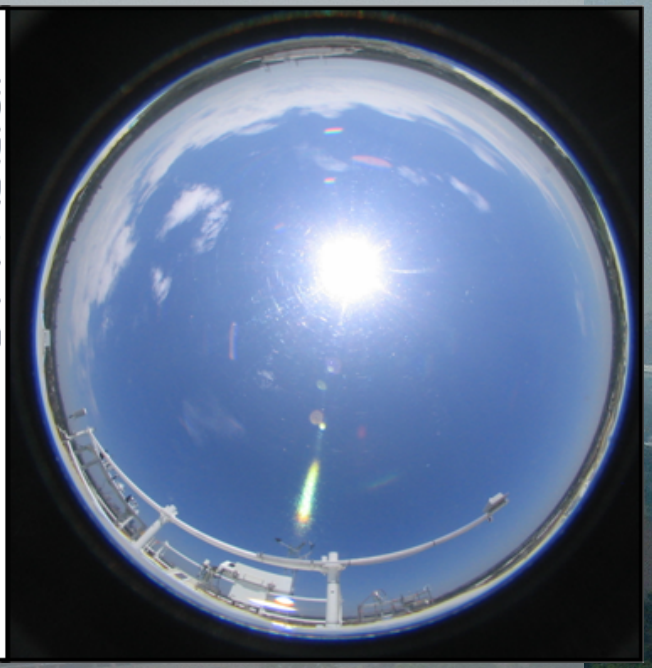


$j(NO_2)$ and j(O1D): Clear sky conditions and sky camera photo

Radiation Measurements

PI:
B. Lefer
(UH)

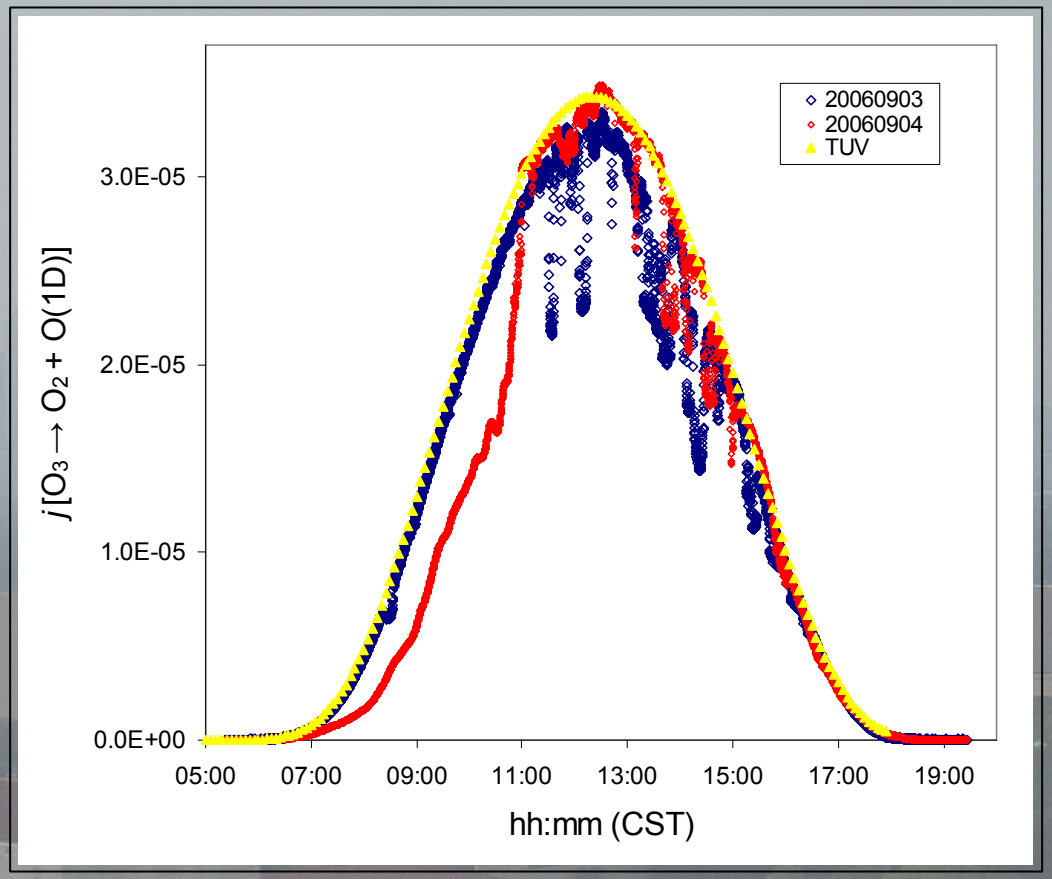




$j(NO_2)$ and j(O1D): At noon sky is "milkier" than under clear sky conditions

Radiation Measurements

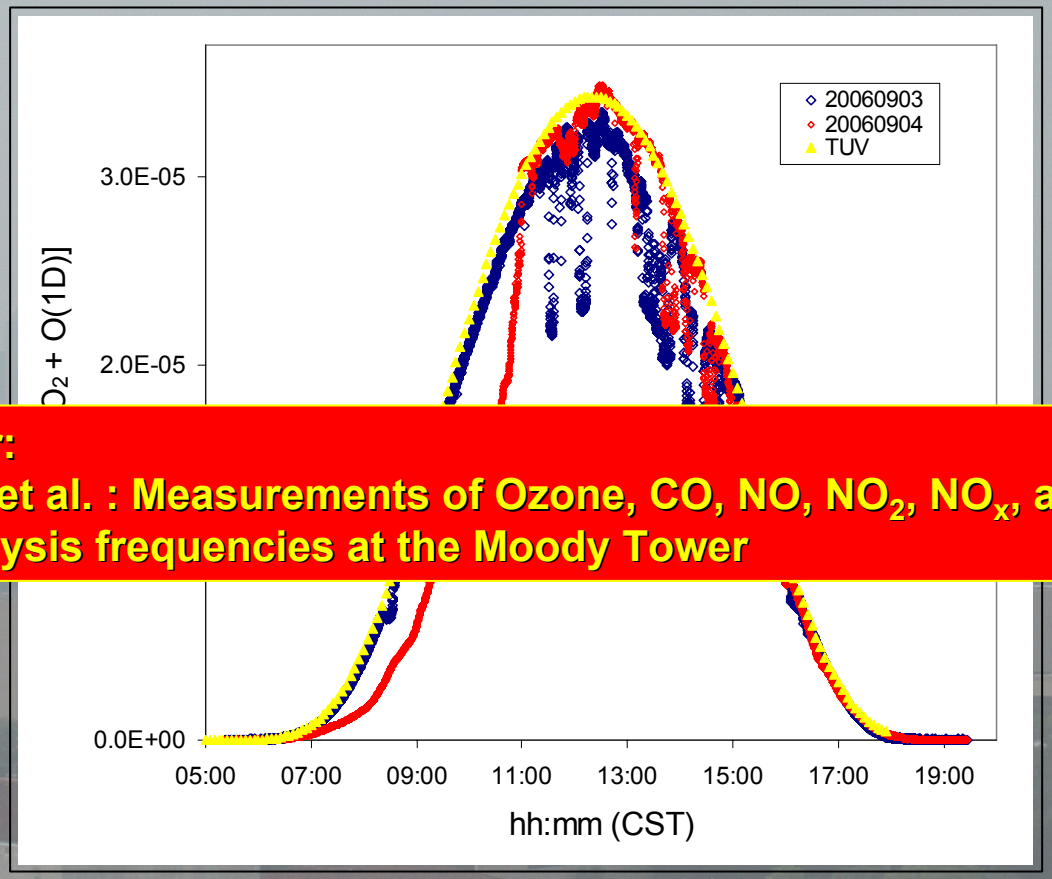
PI:
B. Lefer
(UH)



Significant changes in photolysis frequencies due to clouds and aerosols observed during the TRAMP campaign, e.g. $j[O_3 \rightarrow O(1D)+O_2]$

Radiation Measurements

PI:
B. Lefer
(UH)



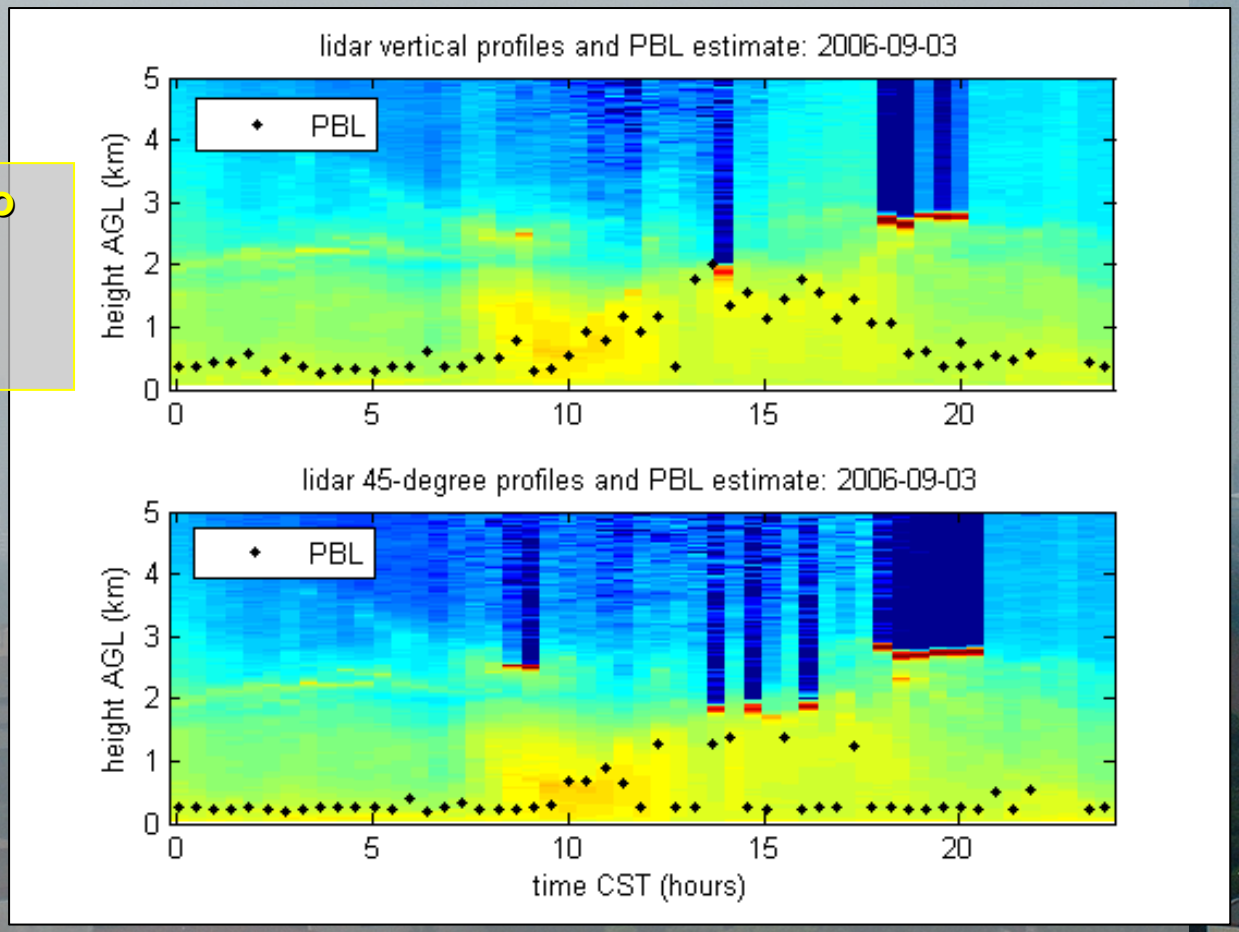
Poster:
Flynn et al. : Measurements of Ozone, CO, NO, NO_2, NO_x, and photolysis frequencies at the Moody Tower

Significant changes in photolysis frequencies due to clouds and aerosols observed during the TRAMP campaign, e.g. $j[O_3 \rightarrow O(1D)+O_2]$

Boundary Layer Studies

PI:
C. Flynn
(UH)

Micropulse LIDAR used to determine planetary boundary layer based on aerosol backscatter



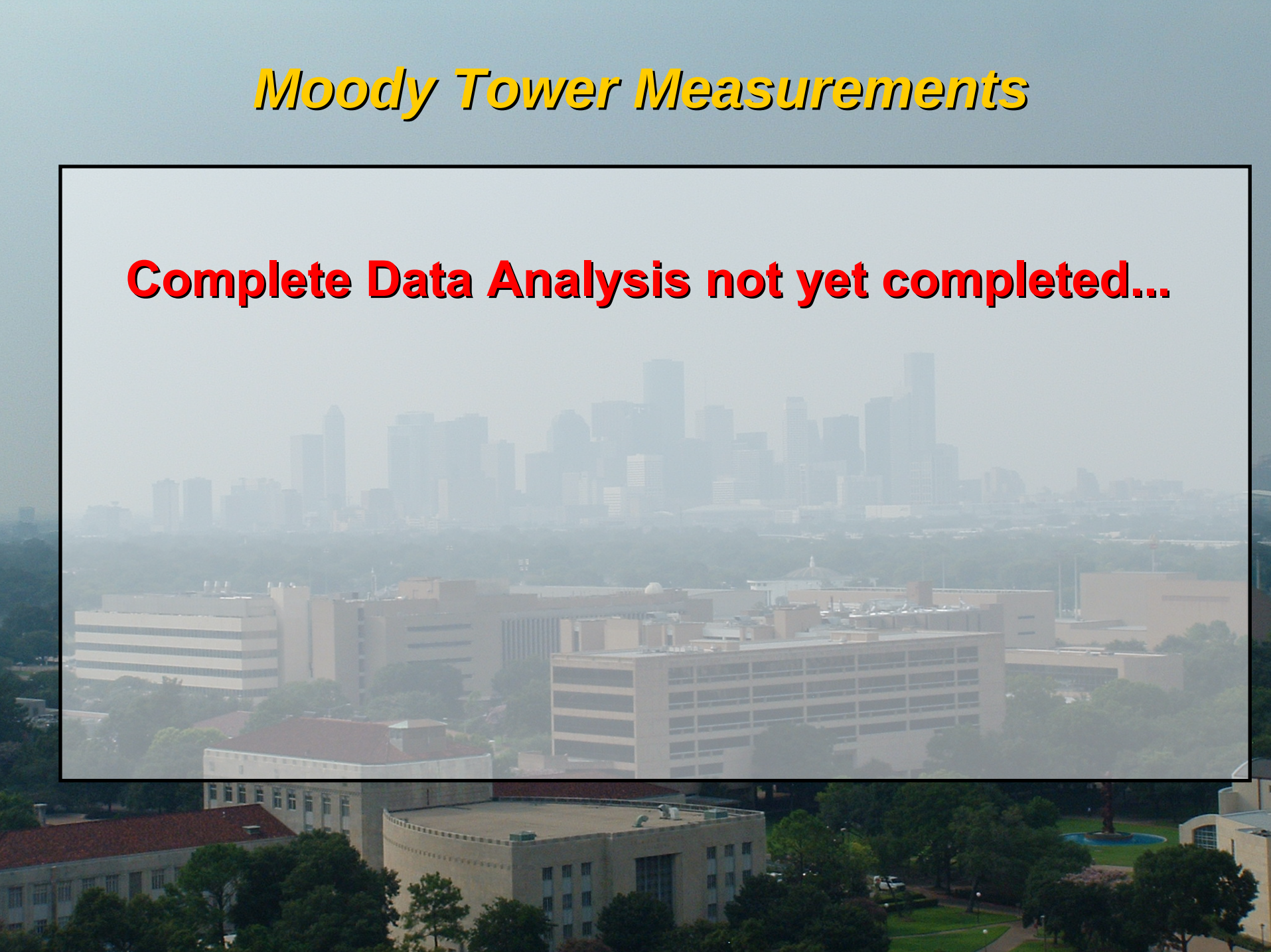
black dots represent a preliminary implementation of a wavelet covariance filter algorithm for detection of the PBL

Moody Tower Measurements

- **Some *preliminary* Results:**
  - Large differences between marine and continental background conditions
  - complex VOC-emissions
    - application of CMAQ with explicit VOC-Chemistry (Aromatics, Alkenes)
  - Highly reactive VOC Chemistry not only during daytime, also nighttime chemistry important:
    - Nighttime OH-formation (e.g. VOC-ractions with NO_3; NO_3 between 60-100 ppt)
    - Nighttime formaldehyde formation (O_3 reaction with alkenes?)
  - High mixing rations of formaldehyde and HONO lead to enhanced production of radicals and subsequent oxidative VOC-degradation and supposingly enhanced formation of SOA
  - Significant particle growth, partly favored through high relative humidity.
  - Significant fraction of organic aerosol.
  - Enhanced fraction of water soluble organics, supposingly due to oxidation of primary organic emissions.

Moody Tower Measurements

Complete Data Analysis not yet completed...



Moody Tower Measurements

Good News:

Comprehensive Final Data Analysis

→ this summer!

(supported by TCEQ and HARC)

Moody Tower Data Analysis Workshop

(tentative dates: July 16-18 at UH)

Thank you !